An Update on Phased Array Results Obtained on the GE Counter-Rotating Open Rotor Model

Gary Podboy NASA GRC

Csaba Horvath Vantage Partners, LLC

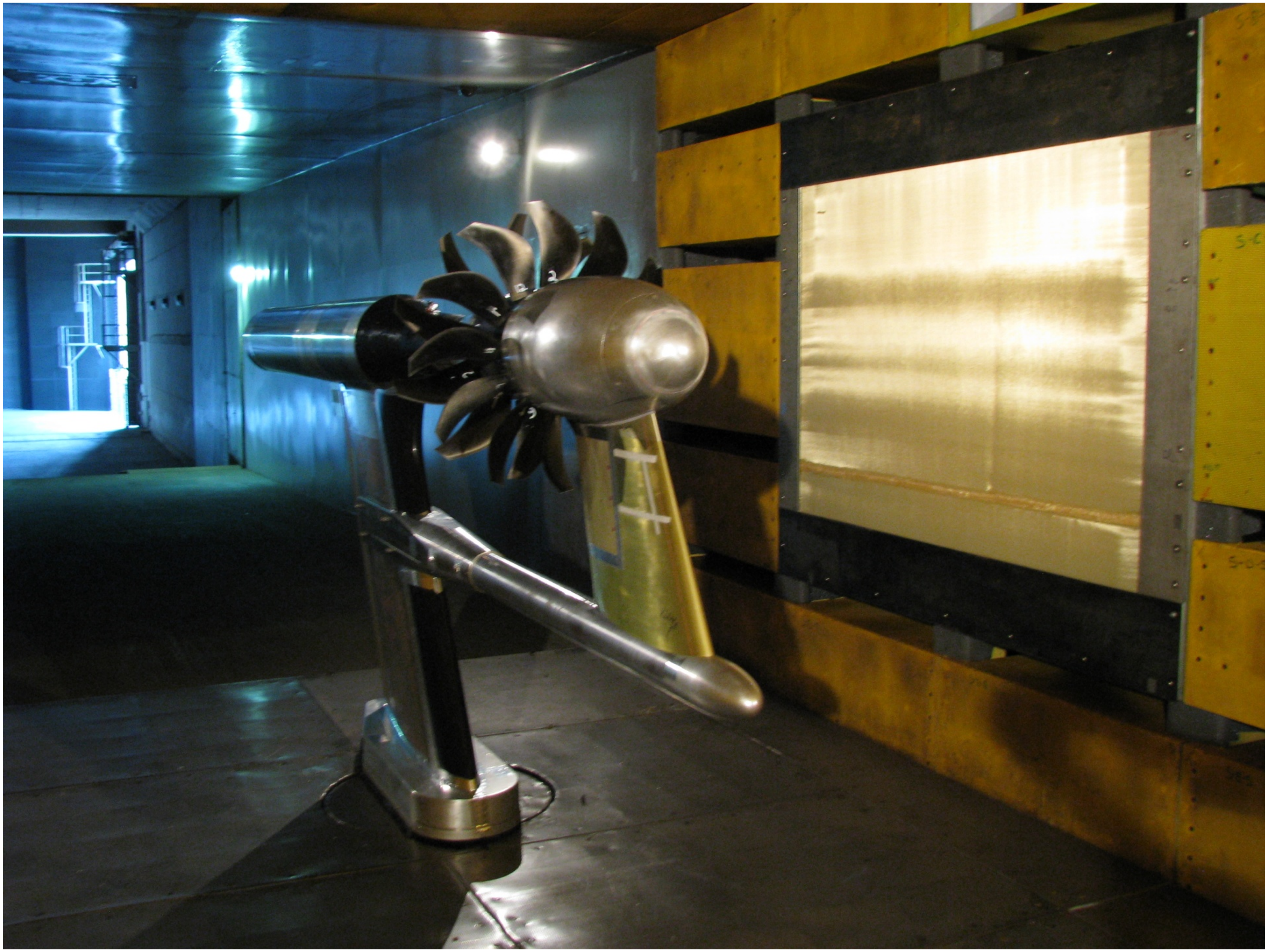
Ed Envia NASA GRC

Acoustics Technical Working Group

April 23 - 24, 2013

Support Provided by the Environmentally Responsible Aviation Project

GE Counter Rotating Open Rotor Model Installed in the NASA Glenn 9 x 15 Ft Wind Tunnel



Data Acquired Using OptiNav Array48

3D Schematic of 9 x 15 Ft Wind Tunnel

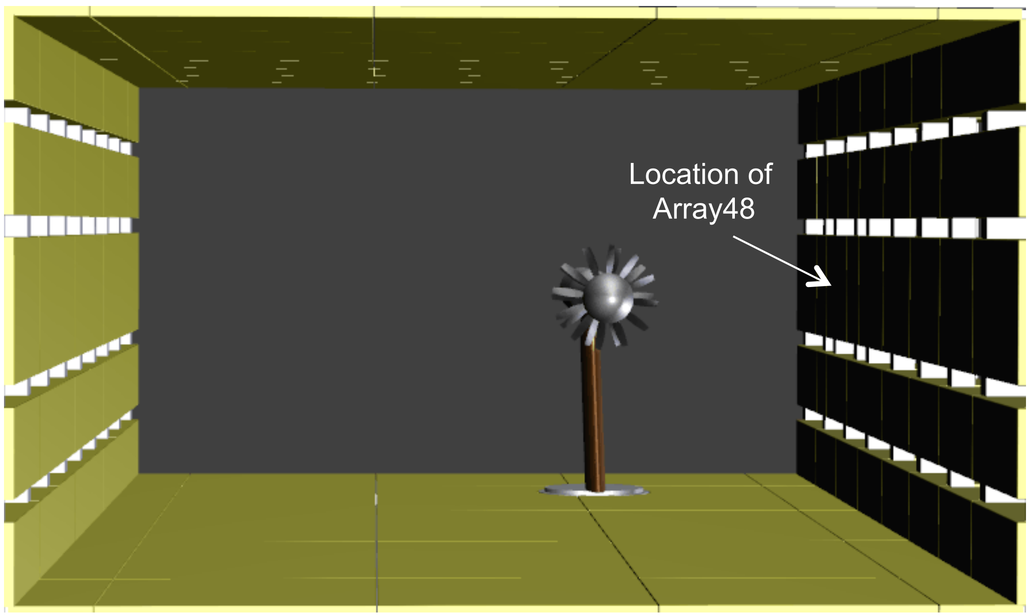
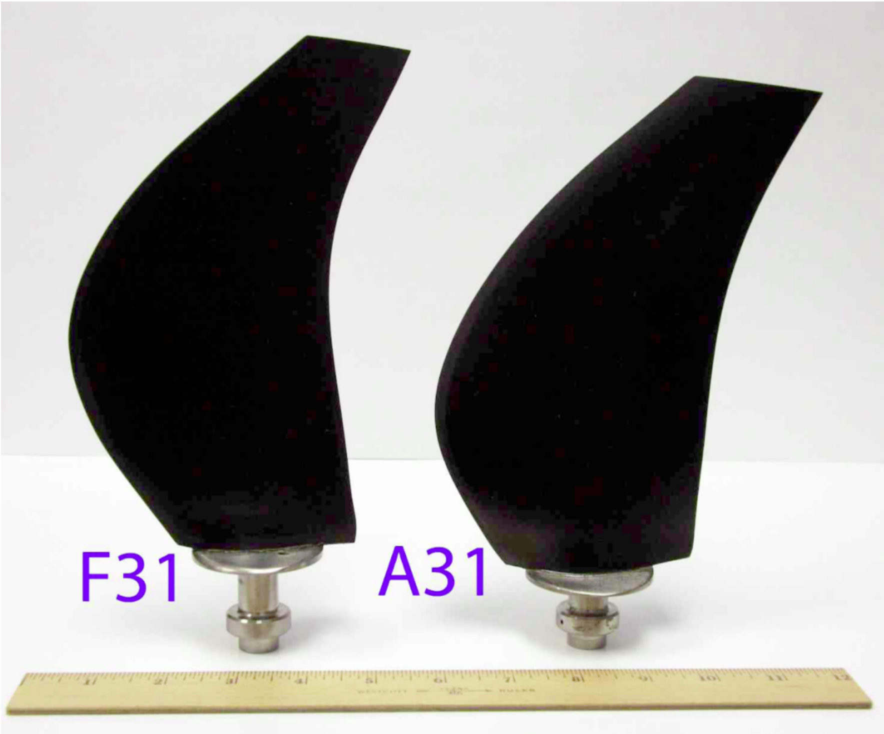


Photo showing Array48 in south wall of Wind Tunnel

F31/A31 Blades



12 Front Rotor Blades 10 Aft Rotor Blades

Front Rotor Speed = Aft Rotor Speed

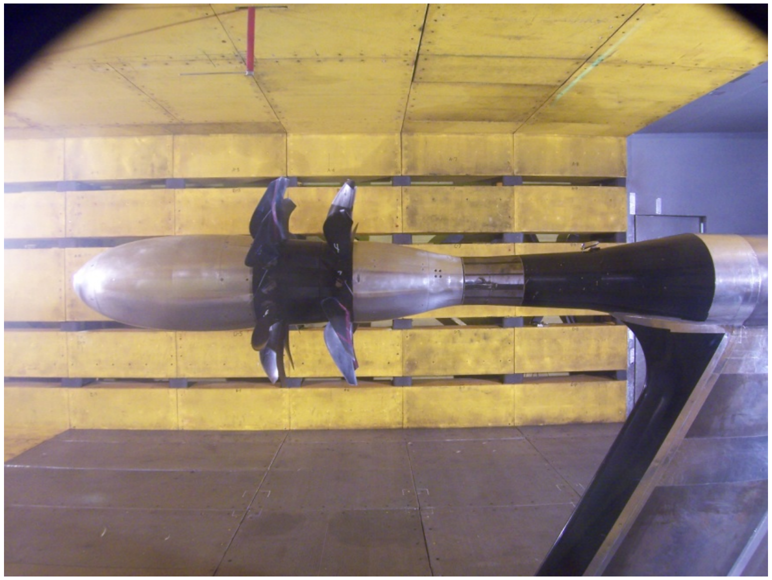
Test Conditions

Corrected Rotor Speeds, RPM

	Approach Blade Angle (33.5°/35.7°)	Take-off Blade Angle (40.1°/40.8°)
Mach 0.2 0° AOA	5598, 6325, 6773, 7245, 7487	4628, 5277, 5561, 6080, 6316, 6450
Mach 0.2 -3° AOA	5598, 6325, 6773	4628, 5561, 6316
Mach 0.2 -8° AOA	5598, 6325, 6773	4628, 5561, 6316
Mach 0.22 0° AOA	5903, 6617, 7054	4880, 5790, 6530

Front Rotor Speed = Aft Rotor Speed
Green designates Approach design speed
Red designates Take-off design speed

No Pylon



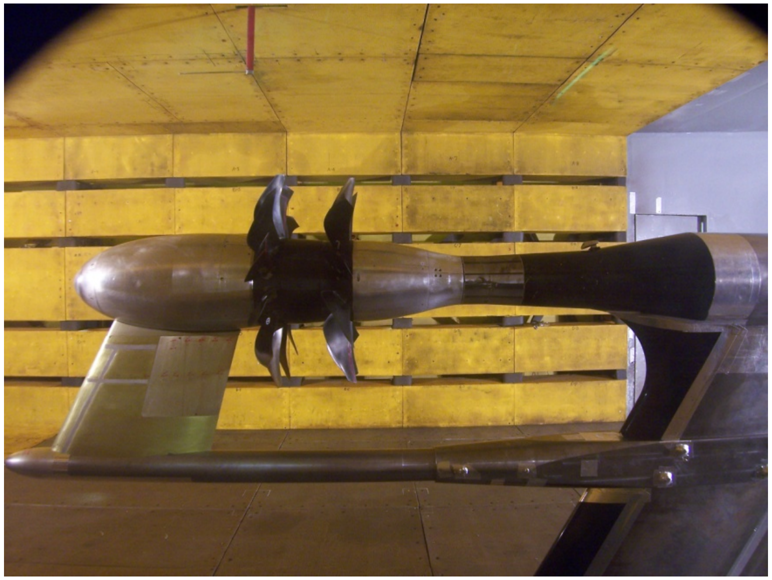
Test Conditions

Corrected Rotor Speeds, RPM

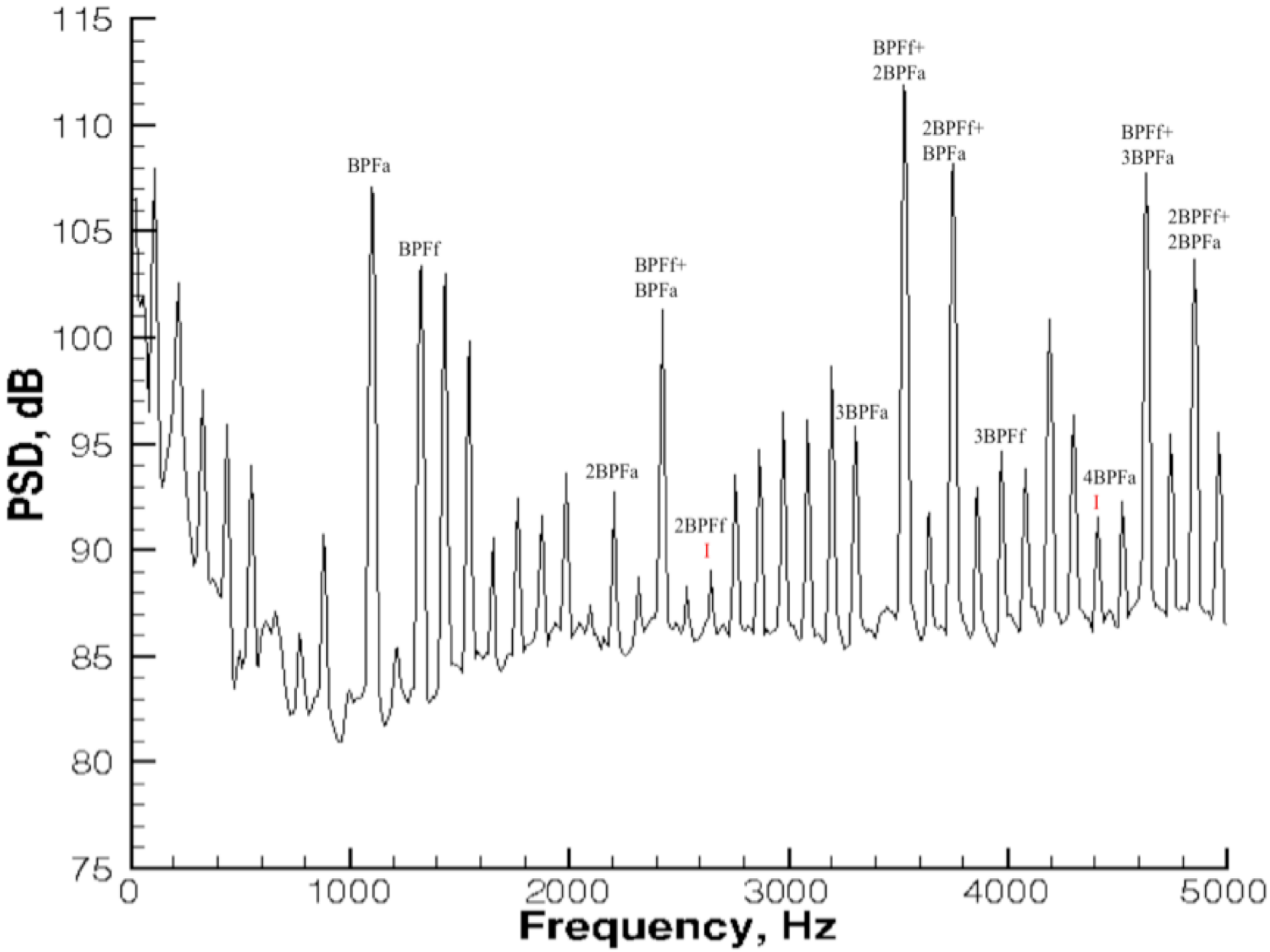
	Approach Blade Angle (33.5°/35.7°)	Take-off Blade Angle (40.1°/40.8°)
Mach 0.2 0° AOA	5598, 6325, 6773, 7245, 7487	4628, 5277, 5561, 6080, 6316, 6450
Mach 0.2 -3° AOA	5598, 6325, 6773	4628, 5561, 6316
Mach 0.2 -8° AOA	5598, 6325, 6773	4628, 5561, 6316
Mach 0.22 0° AOA	5903, 6617, 7054	4880, 5790, 6530

Front Rotor Speed = Aft Rotor Speed
Green designates Approach design speed
Red designates Take-off design speed

Pylon



Want to determine source location of each tone and the broadband noise between the tones



Data Processing

Data processed between 0.5 BPFA and 15 BPFA

5 frequency bins between consecutive shaft orders

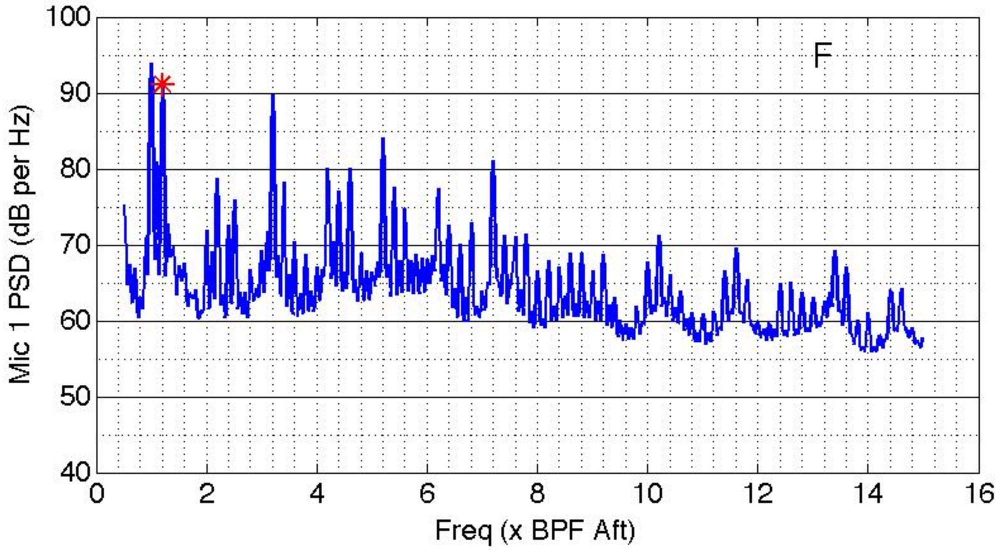
725 beamform maps per operating condition

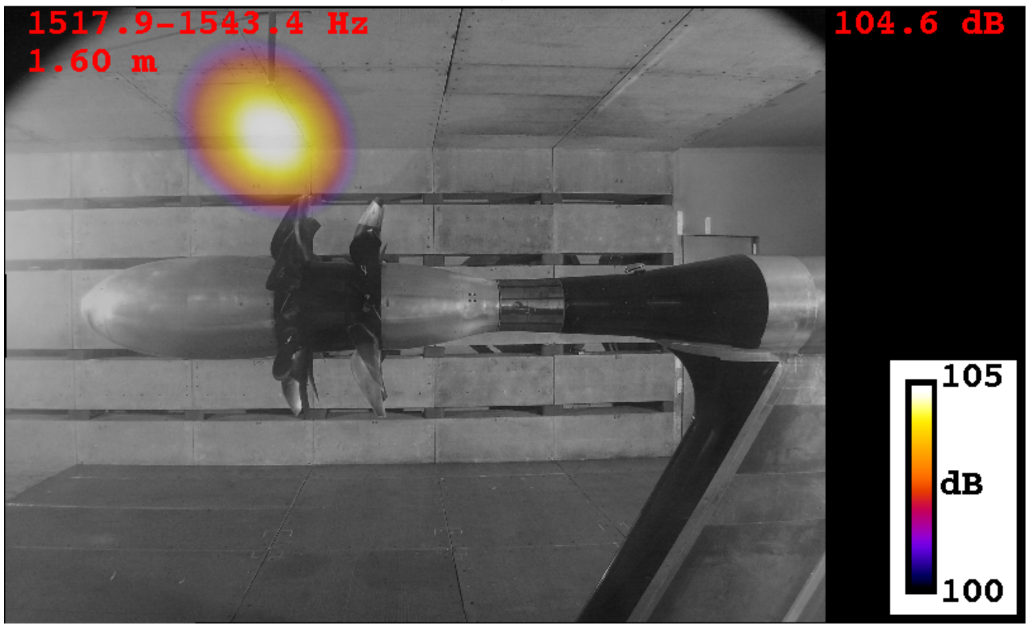
Purpose

To determine the location of the dominant noise sources

Data Processing Issues

Are the source locations accurate?





1F tone

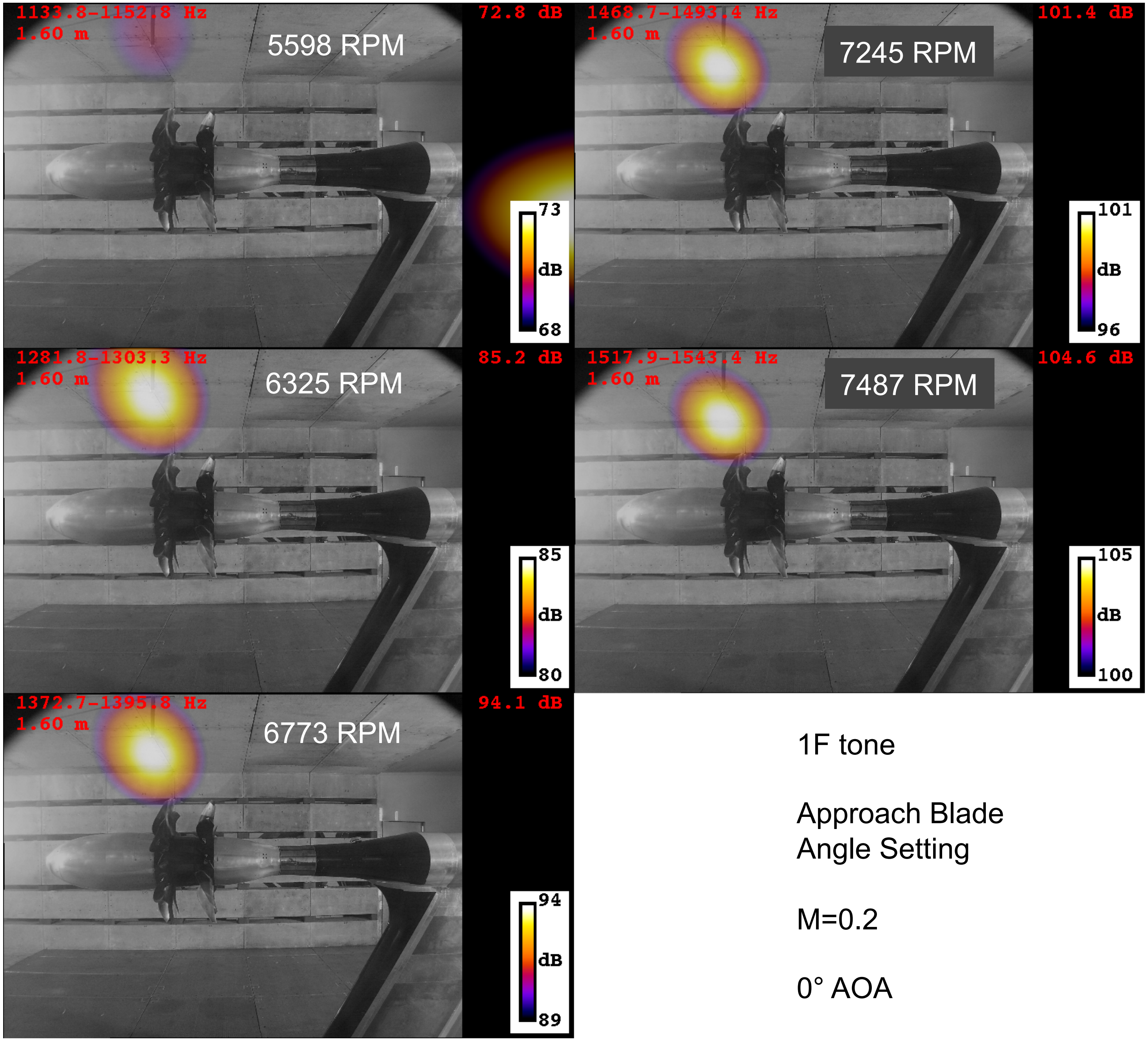
7487 RPMC

Approach Blade Angle Setting

M=0.2

0° AOA

Are the source locations accurate?



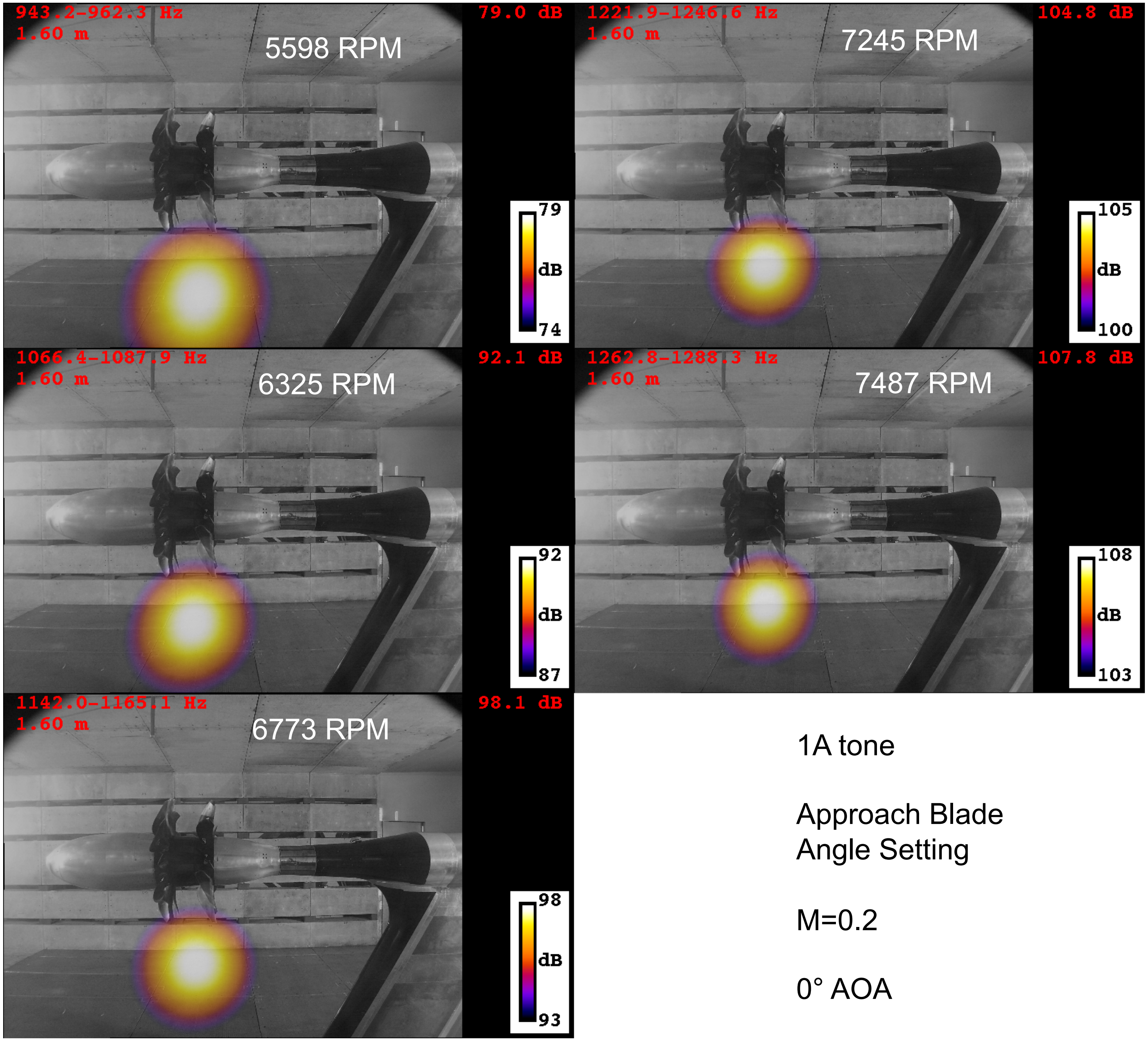
1F tone

Approach Blade
Angle Setting

M=0.2

0° AOA

Are the source locations accurate?



1A tone

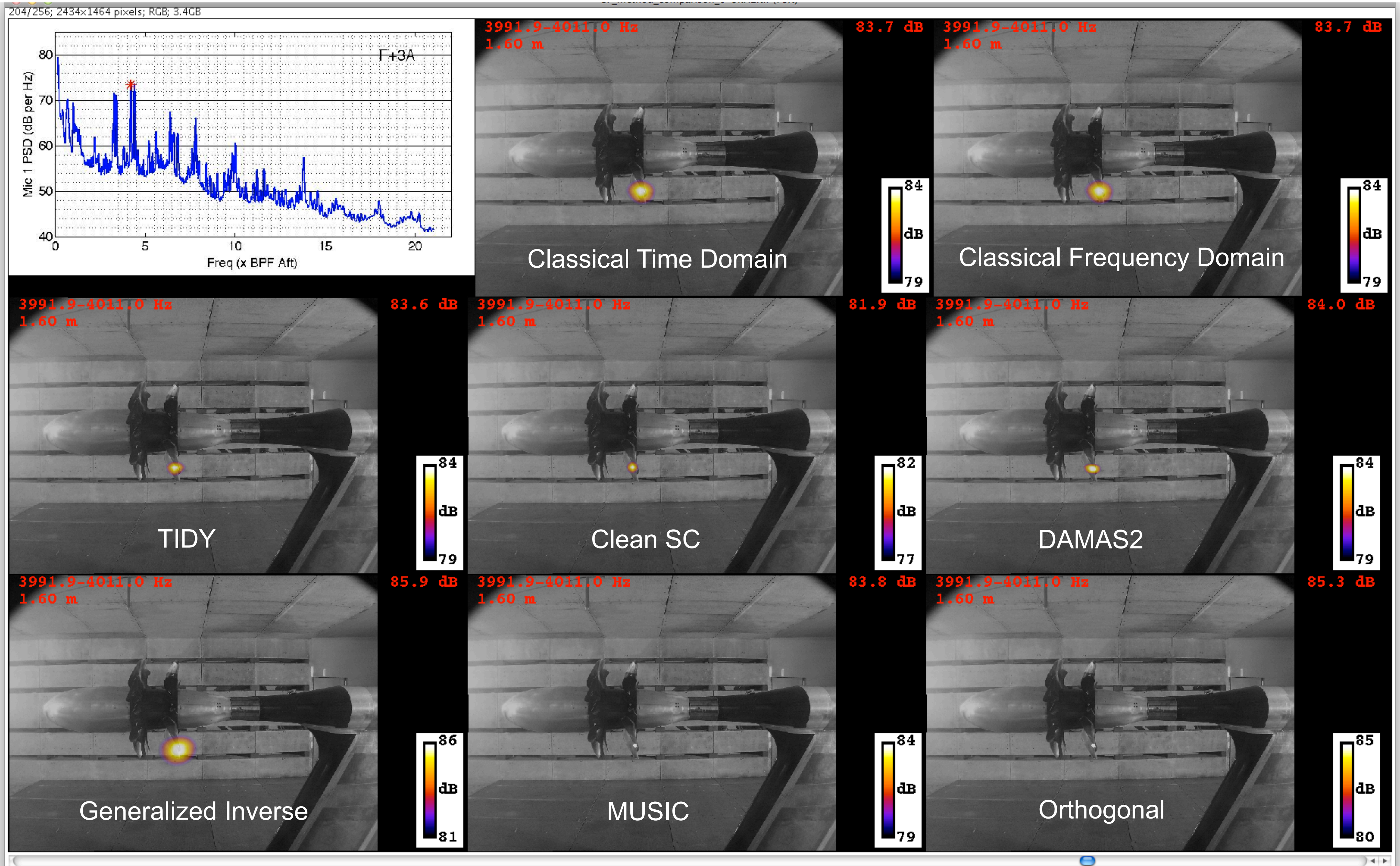
Approach Blade
Angle Setting

M=0.2

0° AOA

Data Processing Issues

Are the source locations accurate?

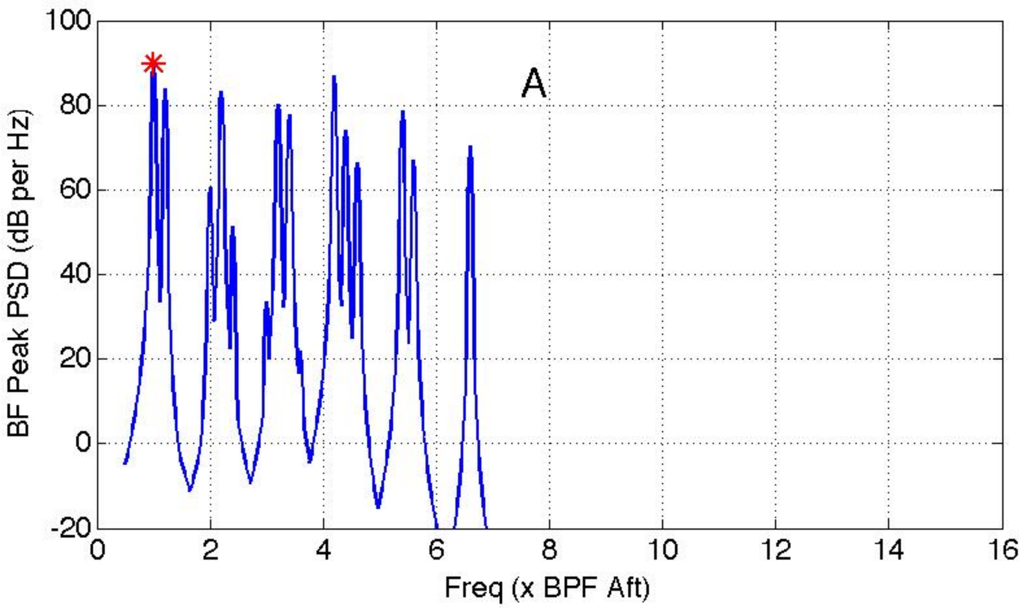


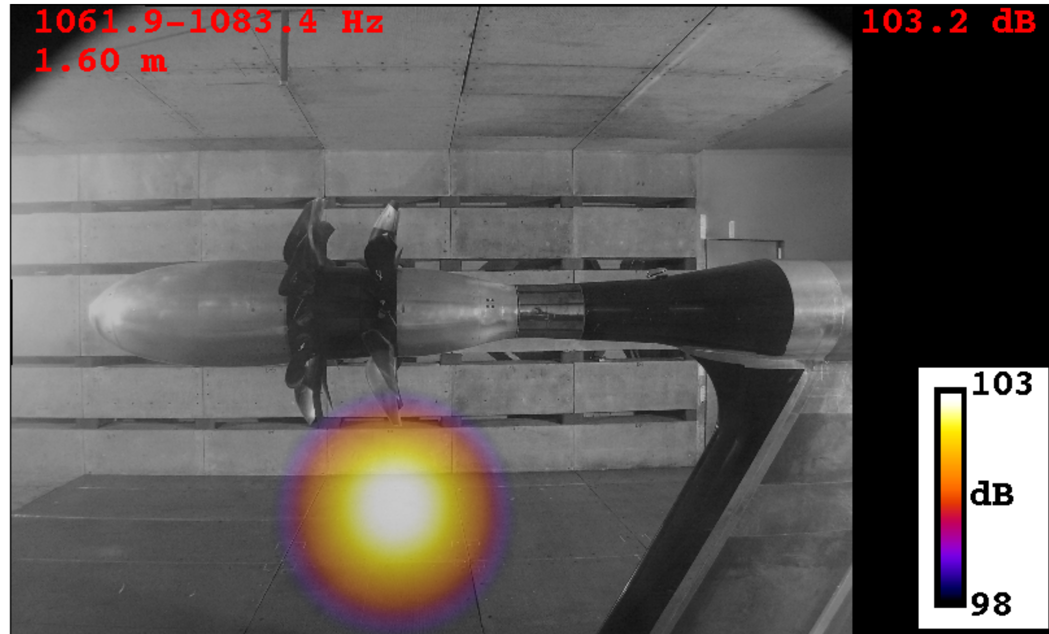
LINPROP Code

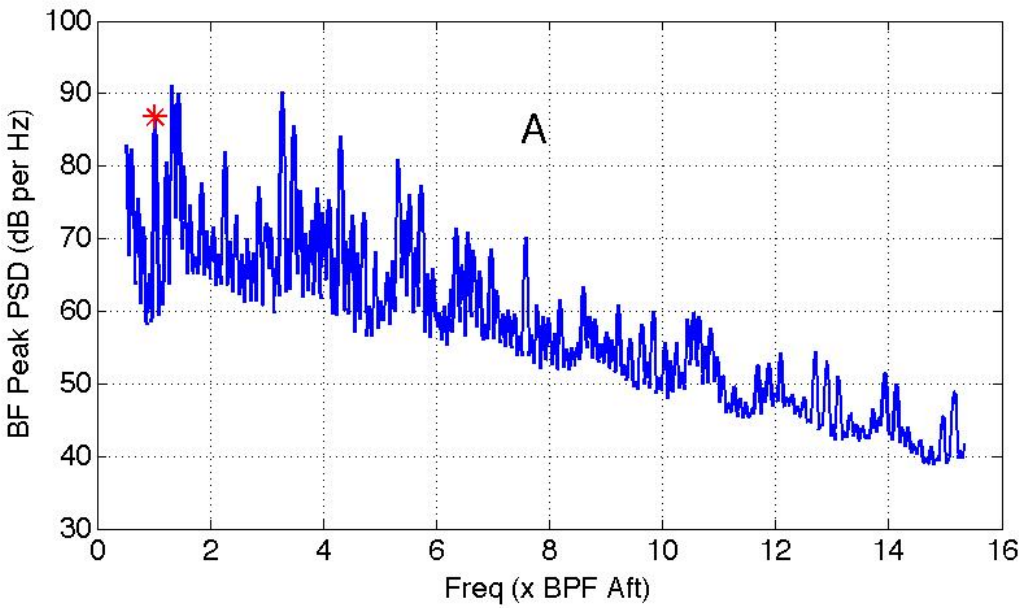
- predicts tones resulting from loading and thickness noise
- assumes identical front rotor blades and identical aft rotor blades

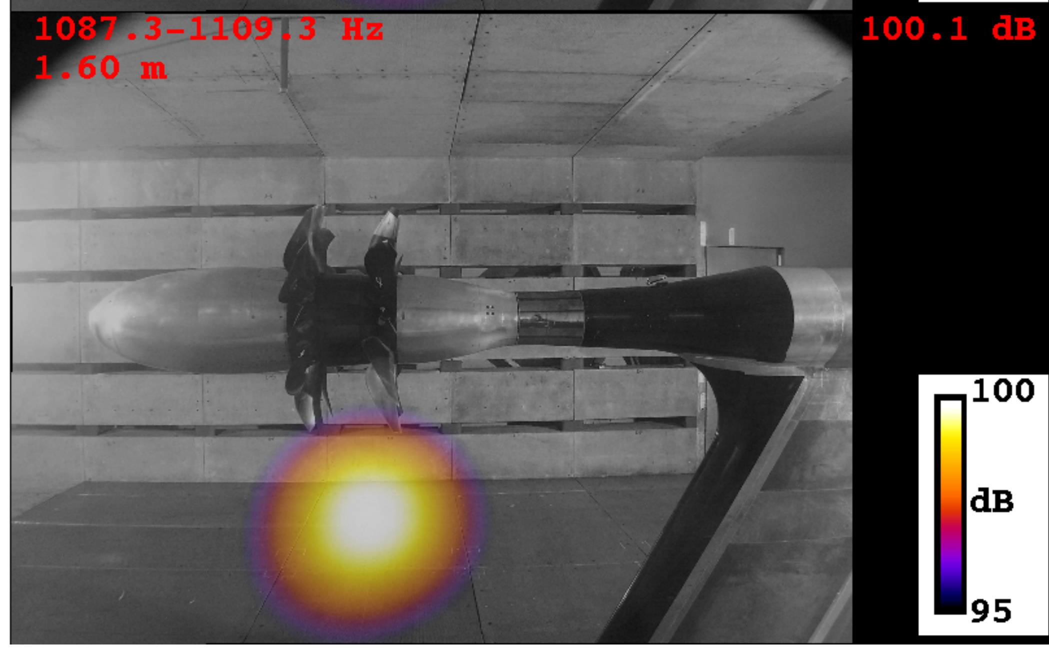
A, F,
2A, F+A, 2F,
3A, F+2A, 2F+A, 3F
F+3A, 2F+2A, 3F+A
2F+3A, 3F+2A
3A+3F

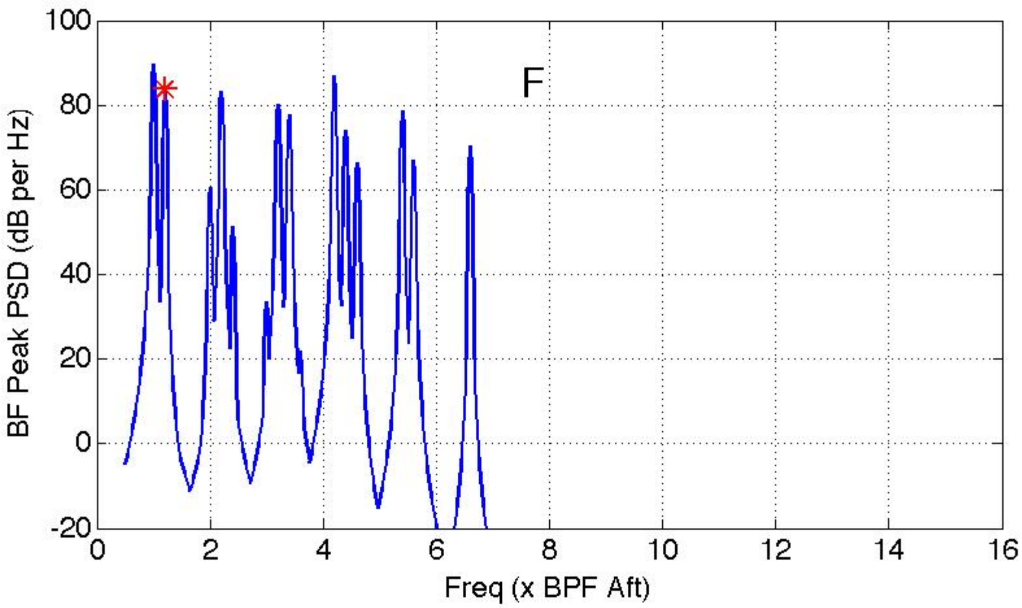
- design speed, take-off blade angle setting, M=0.2, 0° AOA
- simulated tones propagated to the 48 mic locations in Array48
- simulated data processed the same as actual experimental data

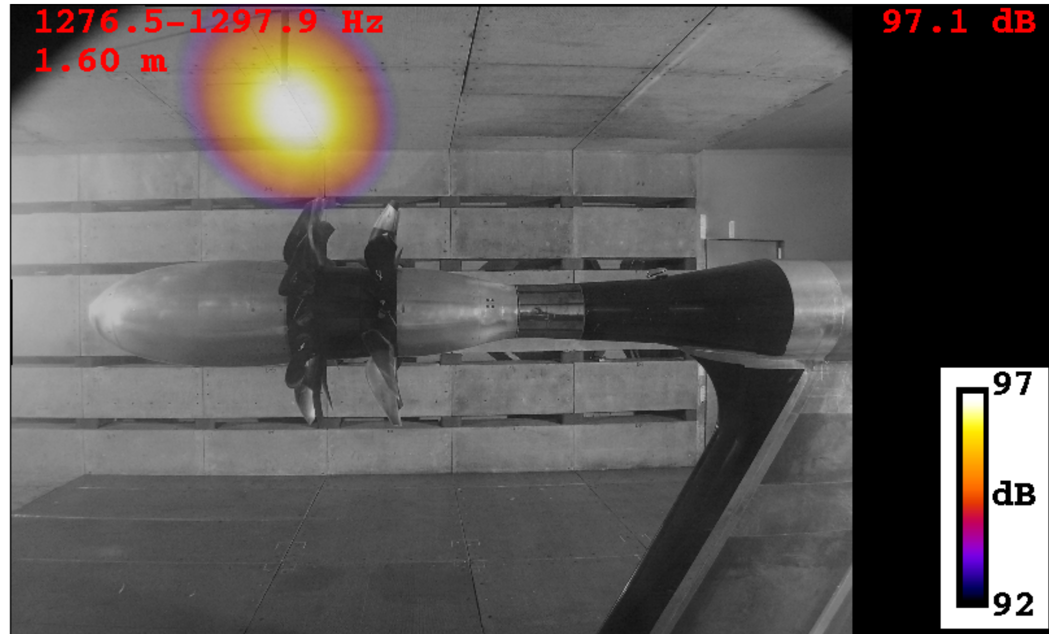

A
BF Peak PSD (dB per Hz)
100
80
60
40
20
0
-20
0
2
4
6
8
10
12
14
16
Freq (x BPF Aft)

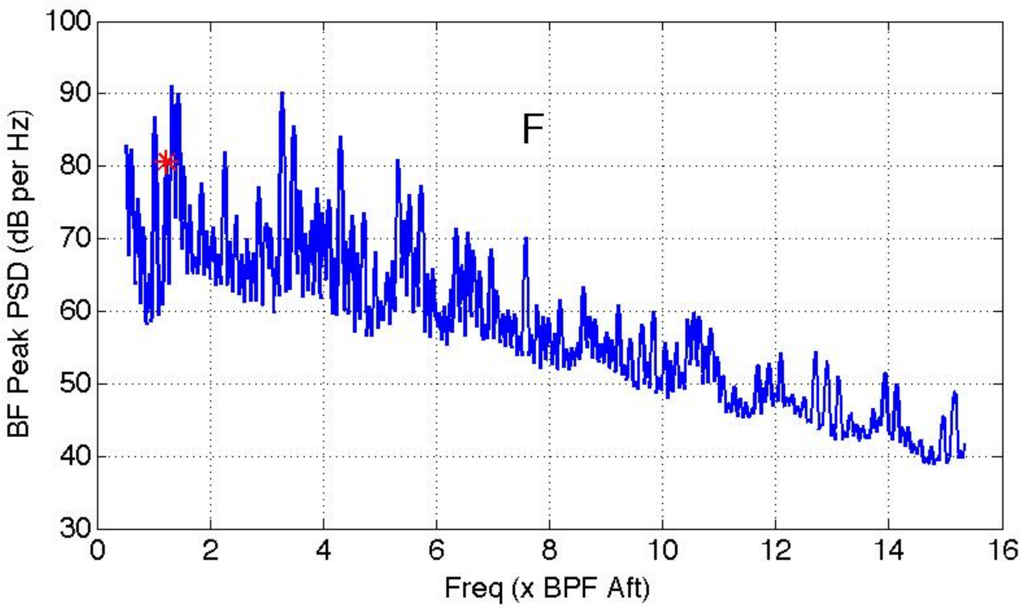

1061.9-1083.4 Hz
1.60 m
103.2 dB
103
dB
98

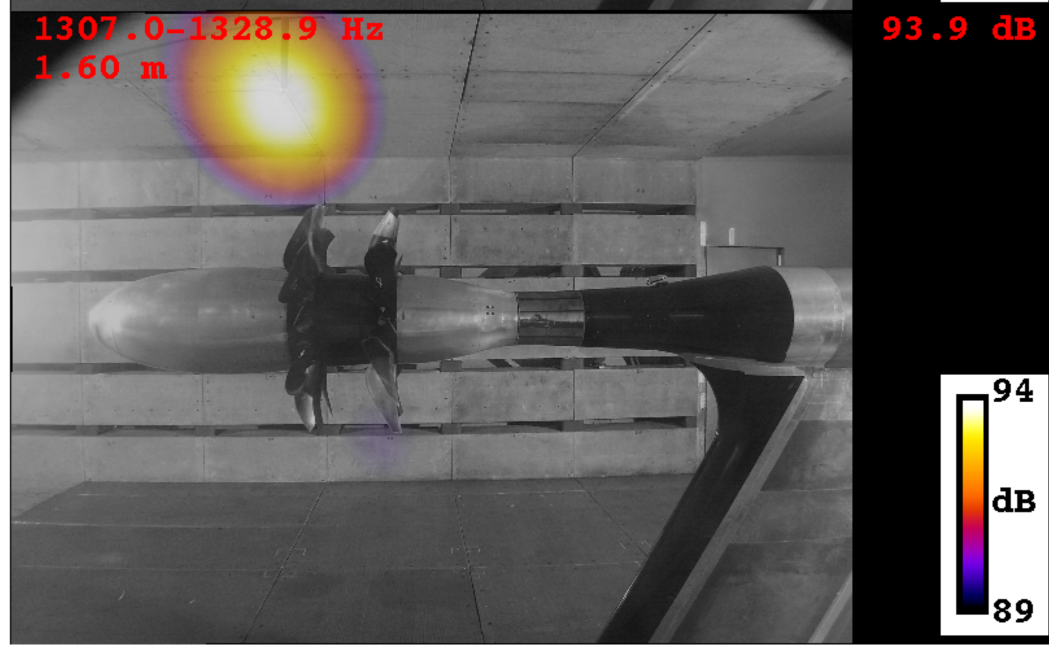

A
BF Peak PSD (dB per Hz)
100
90
80
70
60
50
40
30
0
2
4
6
8
10
12
14
16
Freq (x BPF Aft)

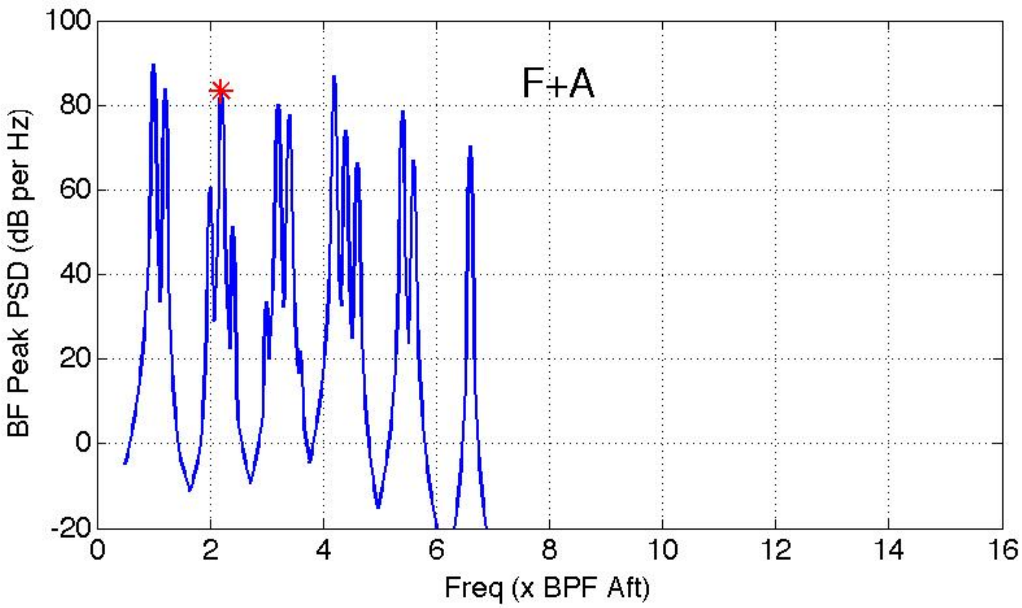

1087.3-1109.3 Hz
1.60 m
100.1 dB
100
dB
95

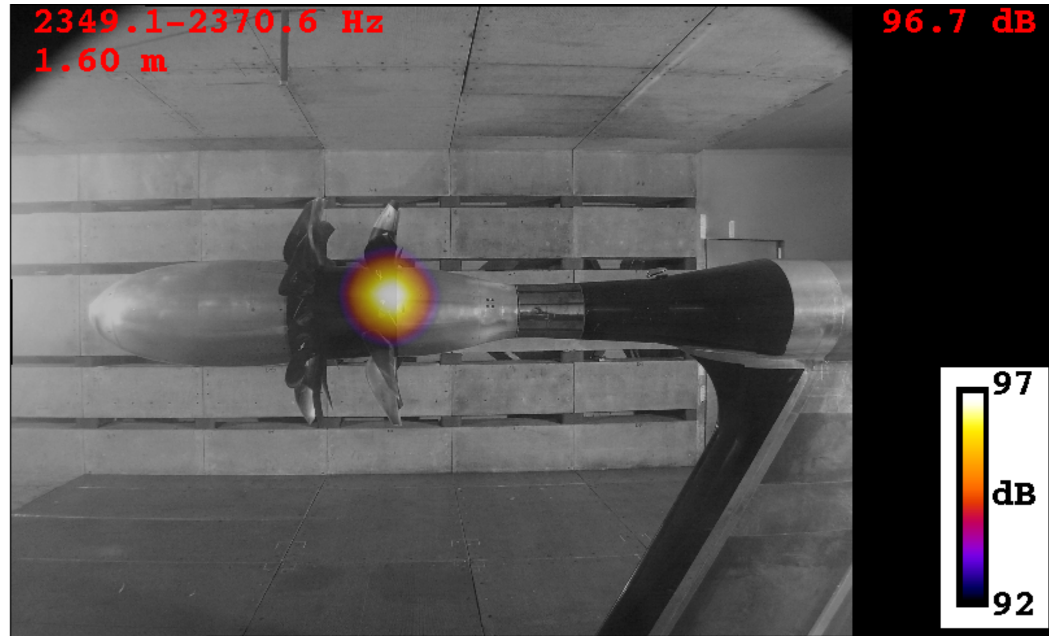

F
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
80
60
40
20
0
-20
0
2
4
6
8
10
12
14
16

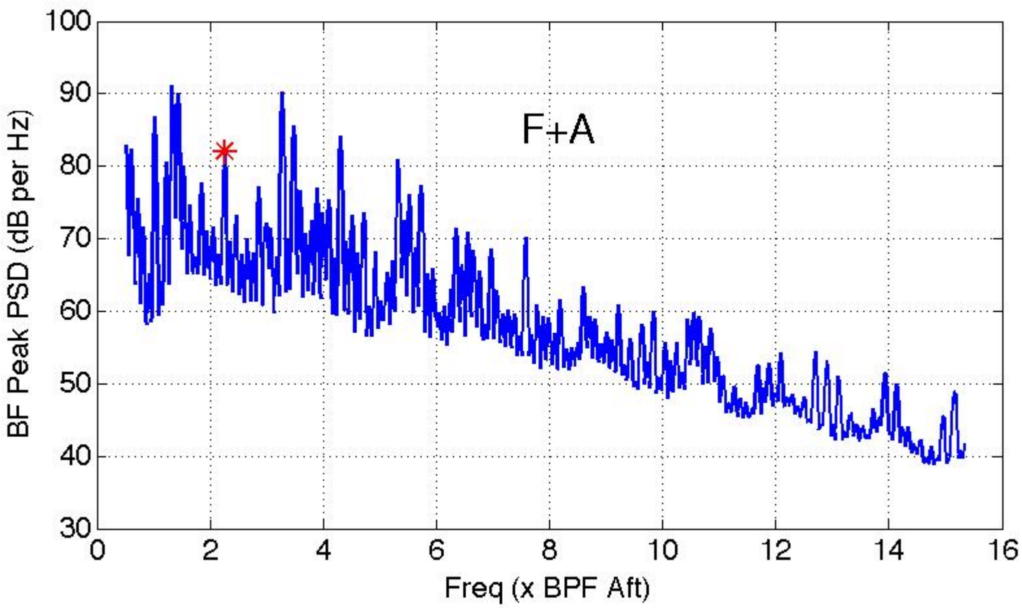

1276.5-1297.9 Hz
1.60 m
97.1 dB
97
dB
92

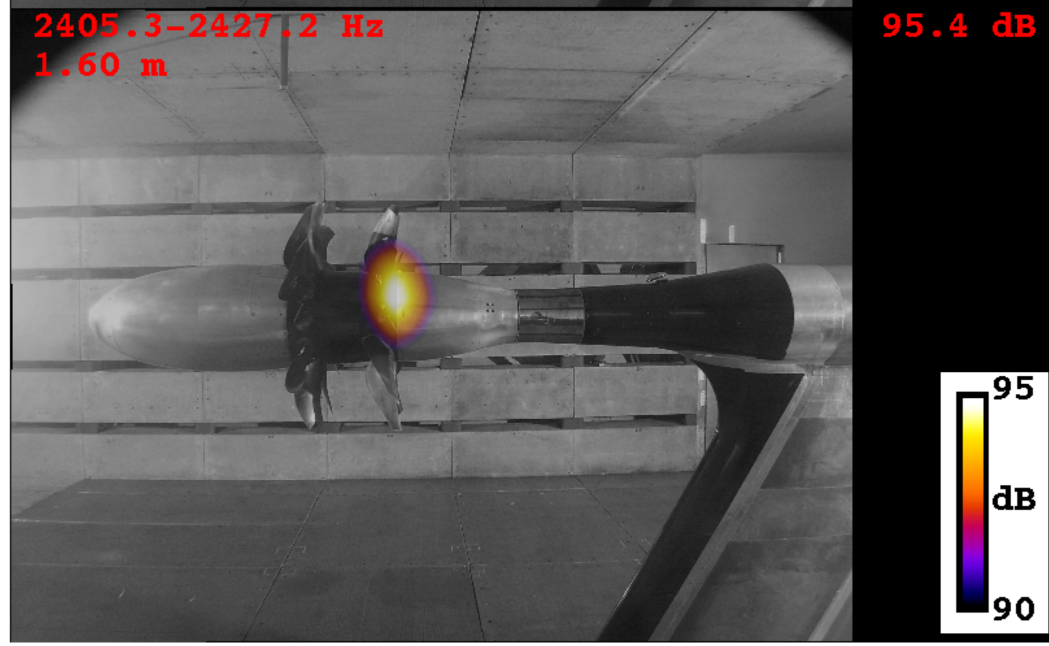

F
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
90
80
70
60
50
40
30
0
2
4
6
8
10
12
14
16

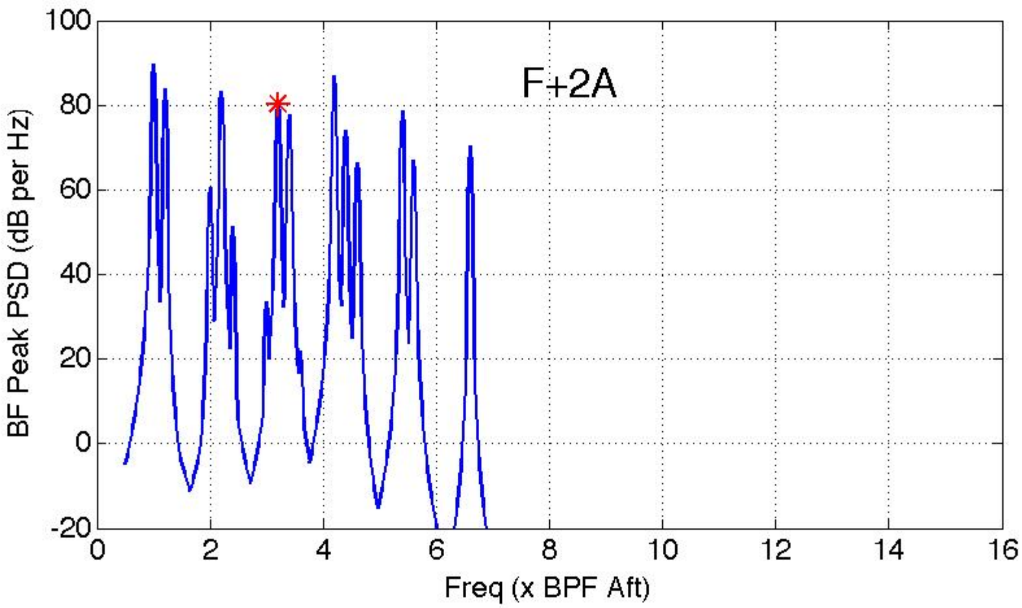

1307.0-1328.9 Hz
1.60 m
93.9 dB
94
dB
89


F+A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
80
60
40
20
0
-20
0
2
4
6
8
10
12
14
16


2349.1-2370.6 Hz
1.60 m
96.7 dB
97
dB
92

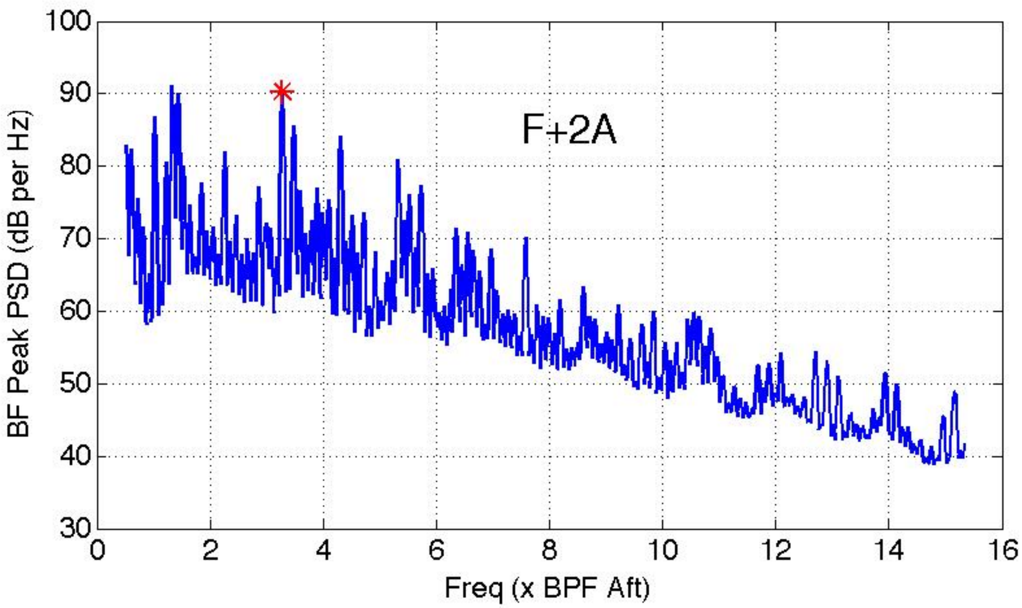

F+A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
90
80
70
60
50
40
30
0
2
4
6
8
10
12
14
16


2405.3-2427.2 Hz
1.60 m
95.4 dB
95
dB
90

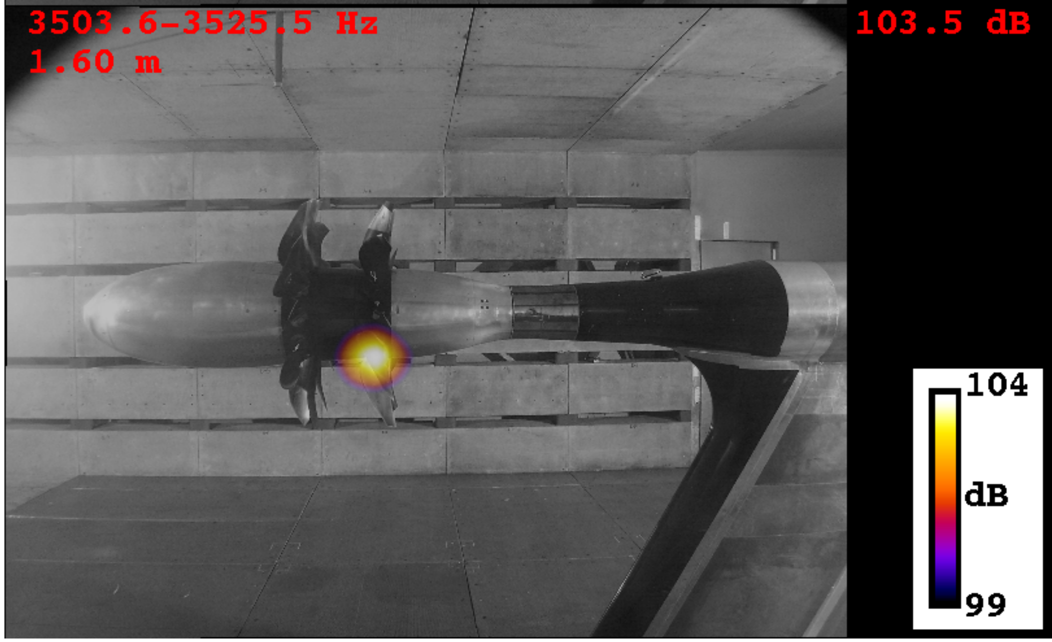


F+2A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)

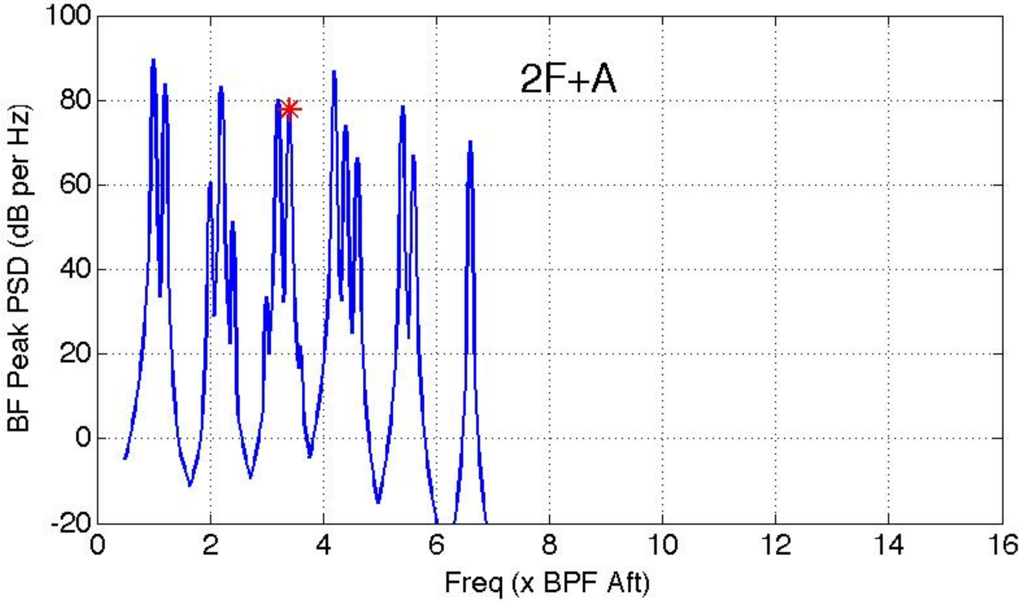
3421.8-3443.3 Hz
1.60 m
93.6 dB
94
dB
89



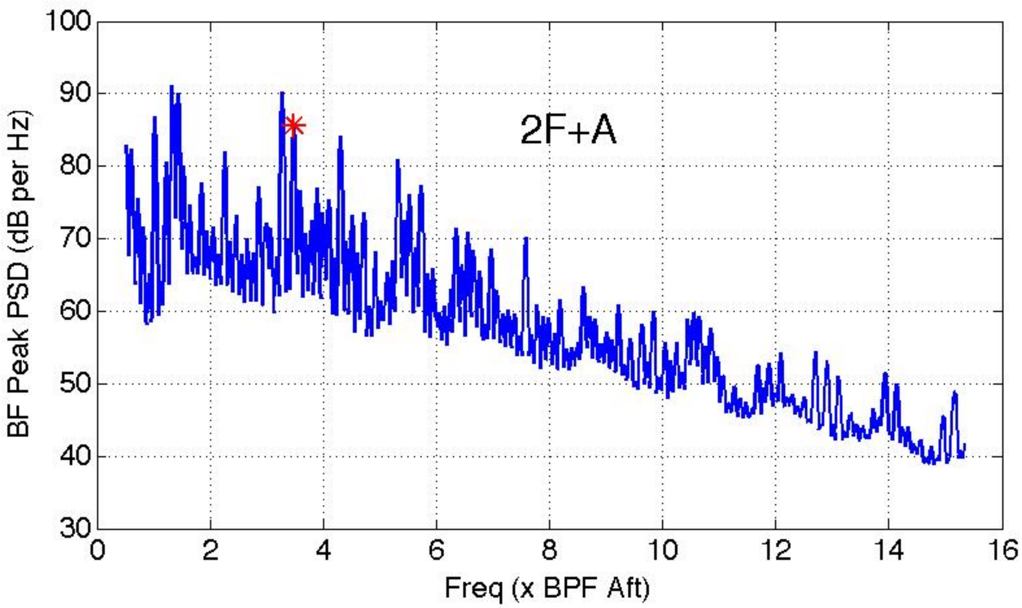
F+2A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)



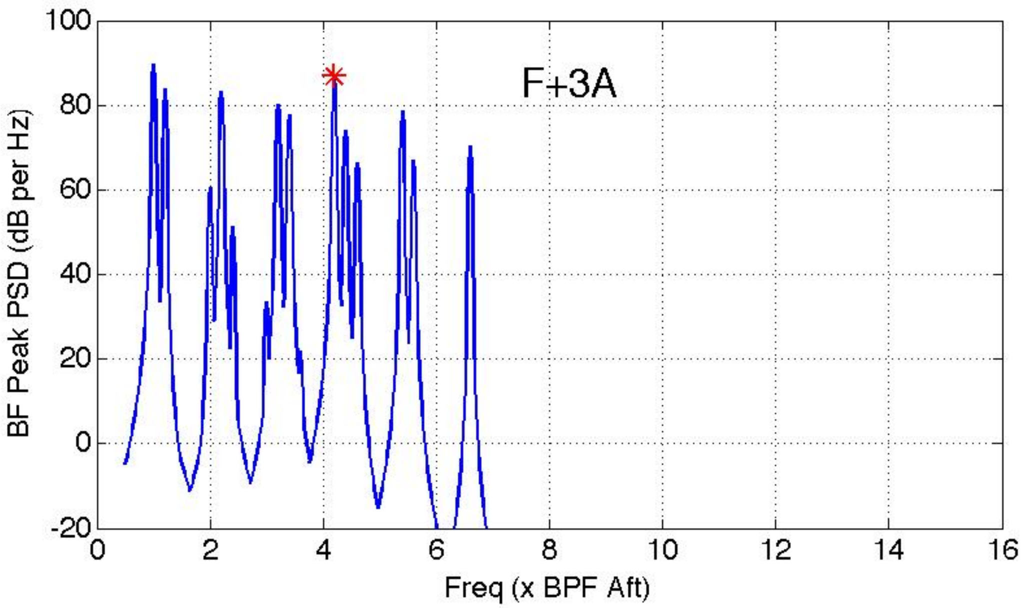
3503.6-3525.5 Hz
1.60 m
103.5 dB
104
dB
99

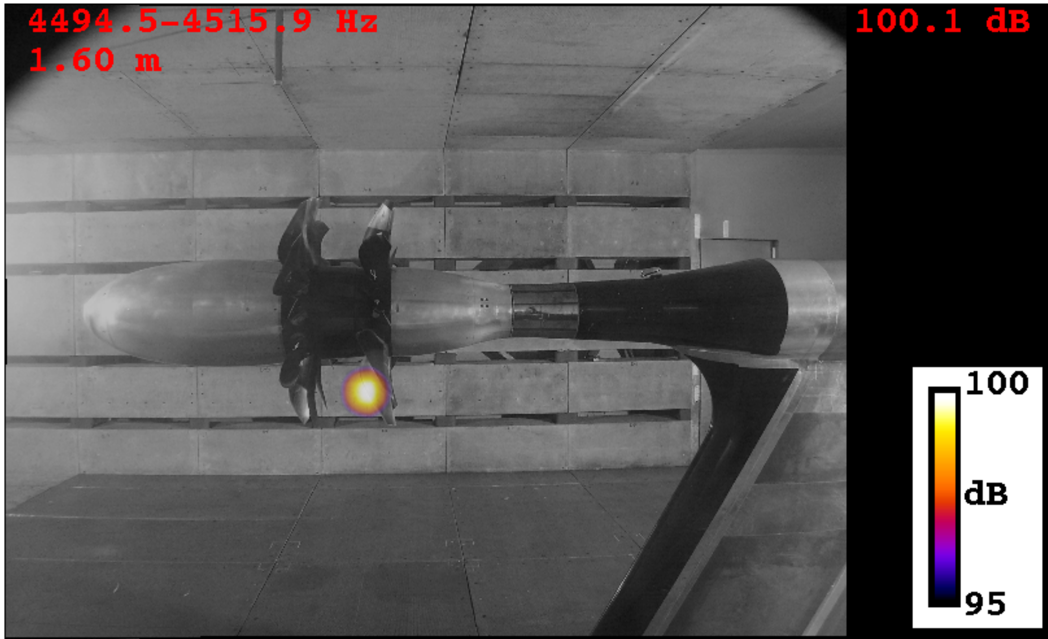

2F+A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
80
60
40
20
0
-20
0
2
4
6
8
10
12
14
16

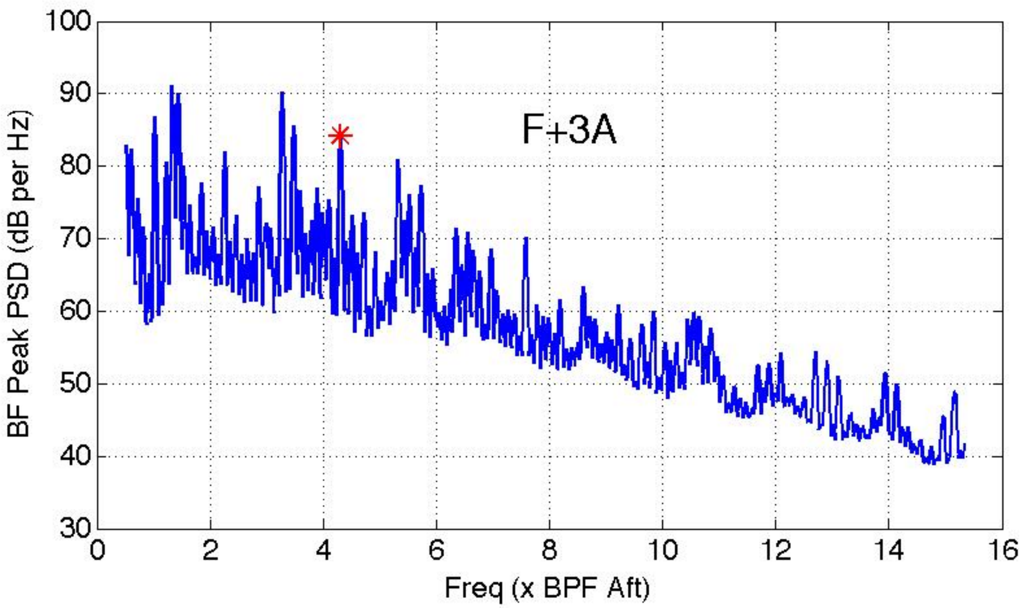

3636.3-3657.8 Hz
1.60 m
91.2 dB
91
dB
86

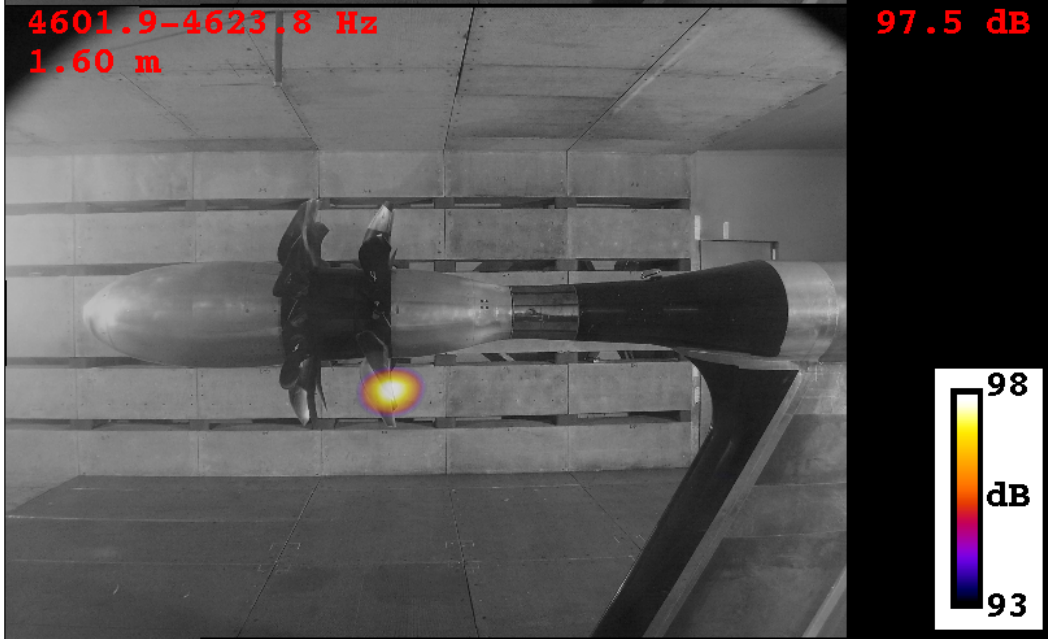

2F+A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
90
80
70
60
50
40
30
0
2
4
6
8
10
12
14
16

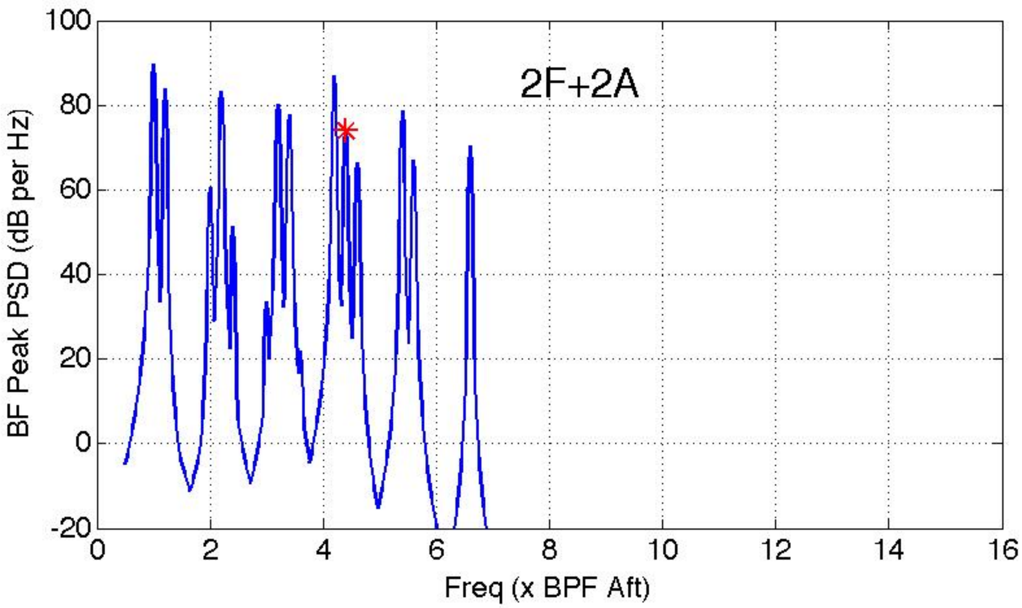

3723.2-3745.2 Hz
1.60 m
98.9 dB
99
dB
94

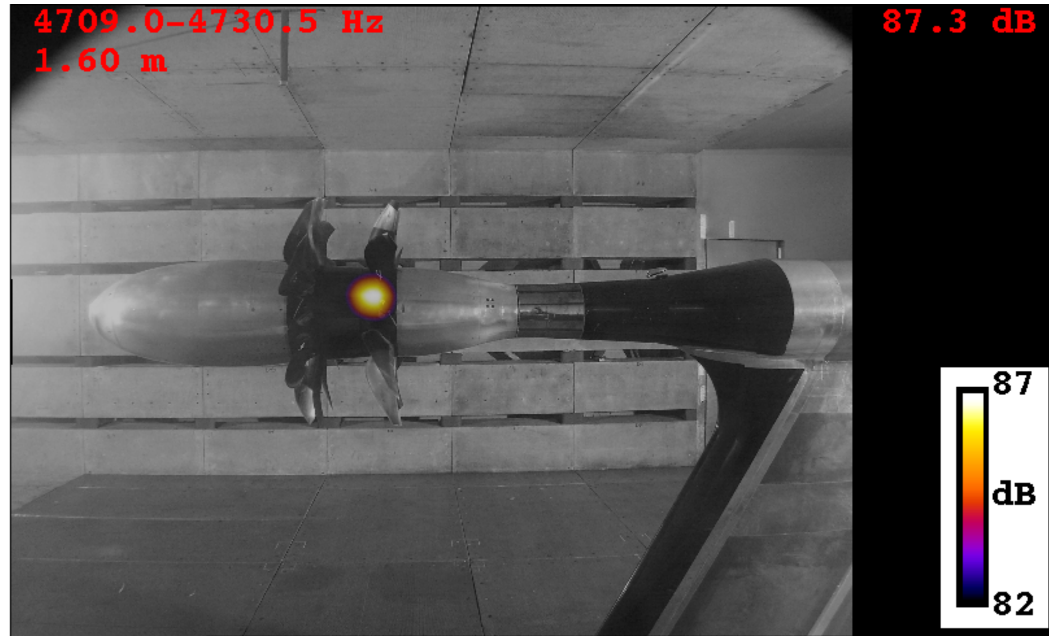

F+3A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)

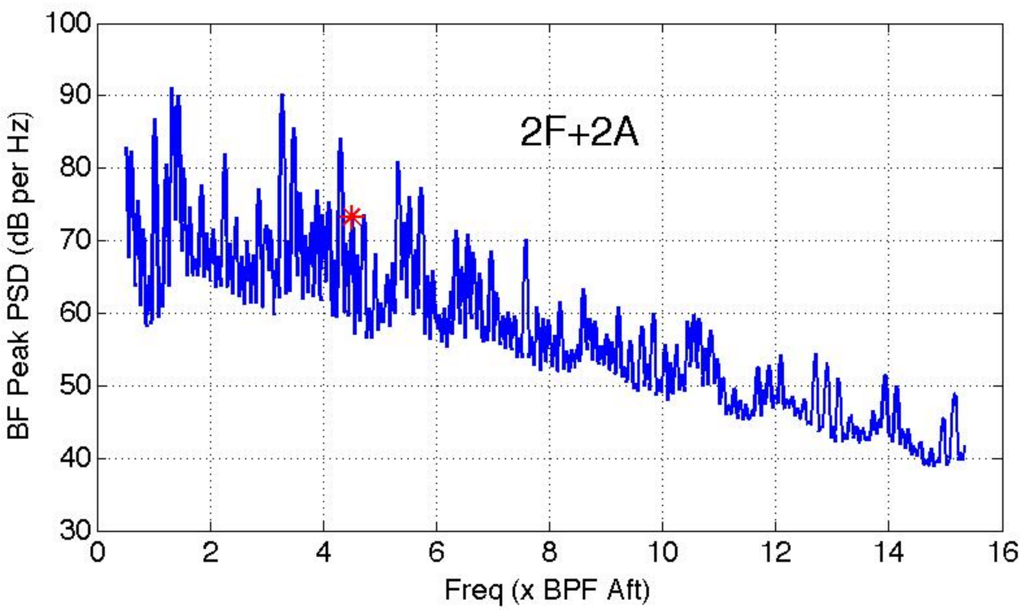

4494.5-4515.9 Hz
1.60 m
100.1 dB
100
dB
95

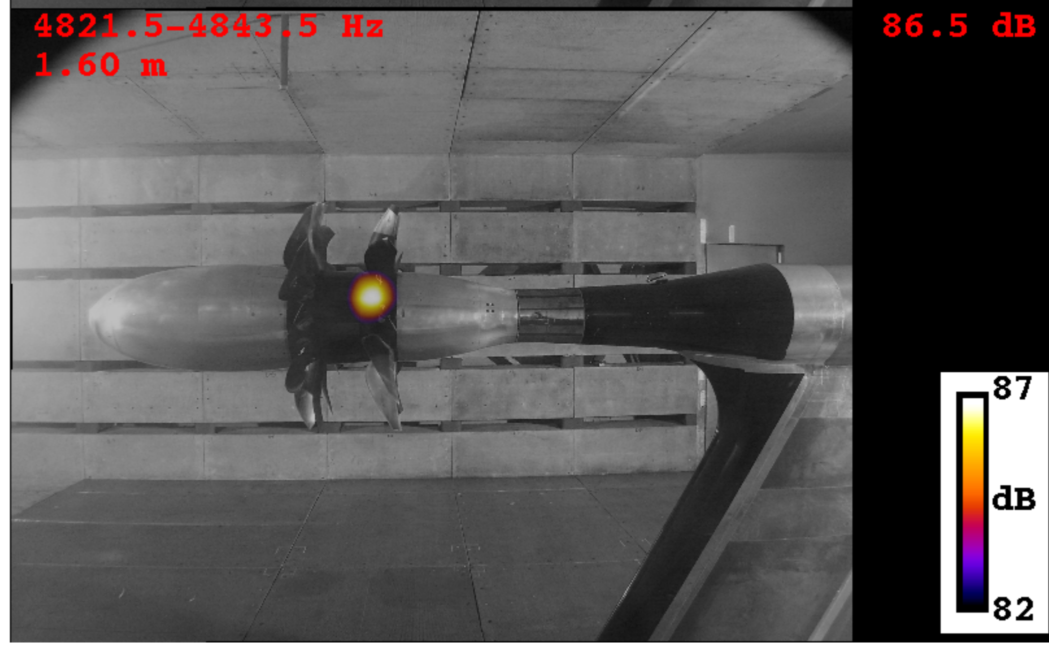

F+3A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)

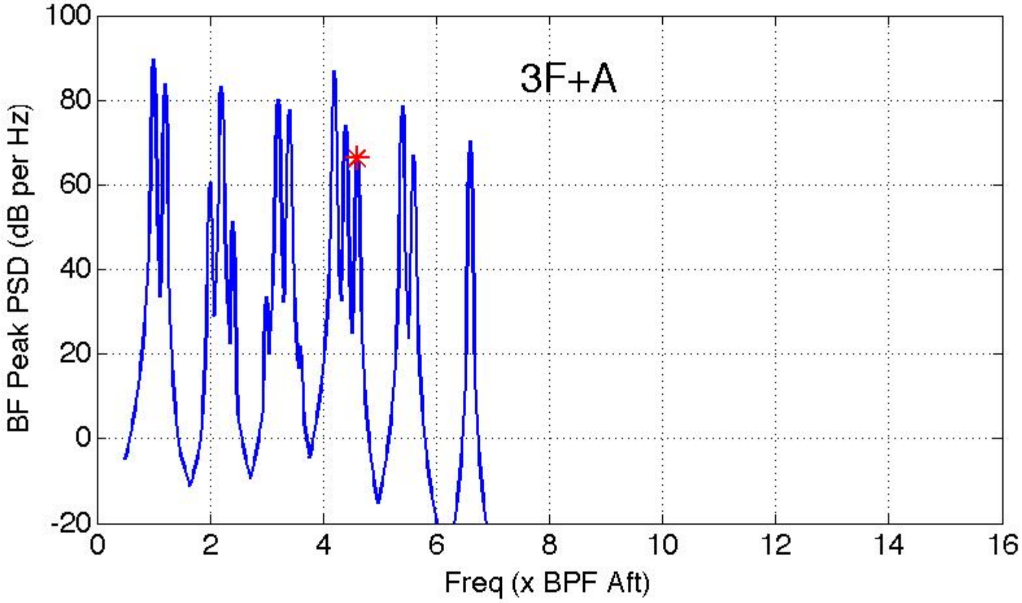

4601.9-4623.8 Hz
1.60 m
97.5 dB
98
dB
93


2F+2A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
80
60
40
20
0
-20
0
2
4
6
8
10
12
14
16

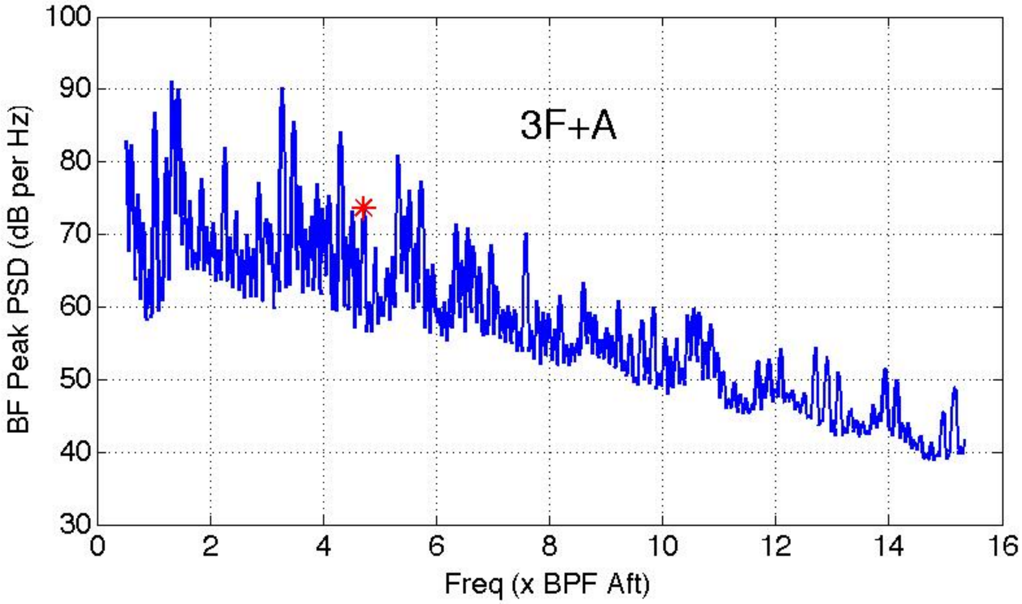

4709.0-4730.5 Hz
1.60 m
87.3 dB
87
dB
82

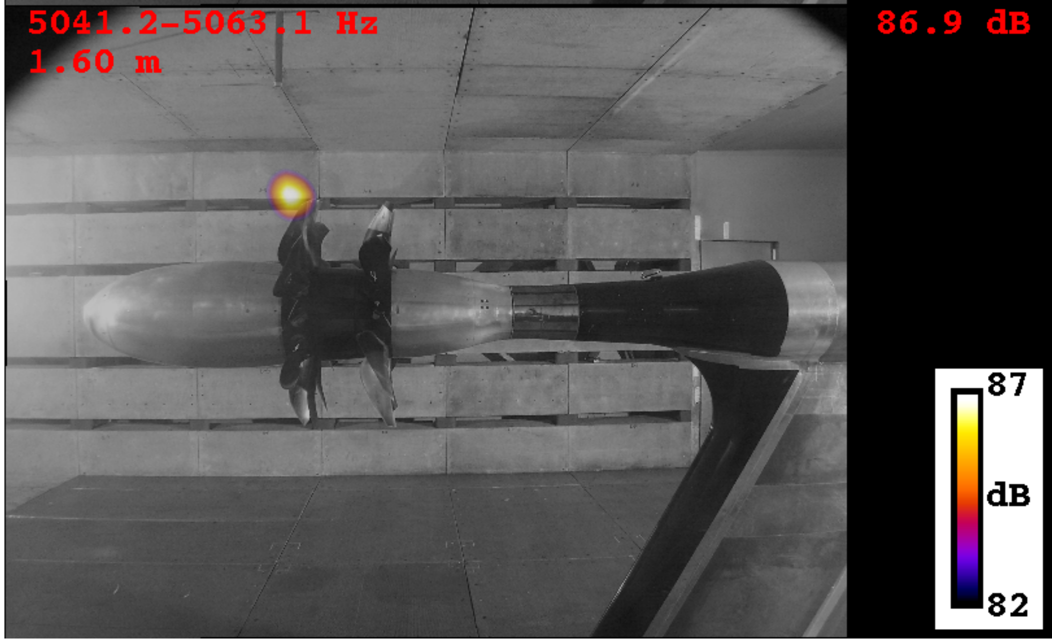

2F+2A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
90
80
70
60
50
40
30
0
2
4
6
8
10
12
14
16

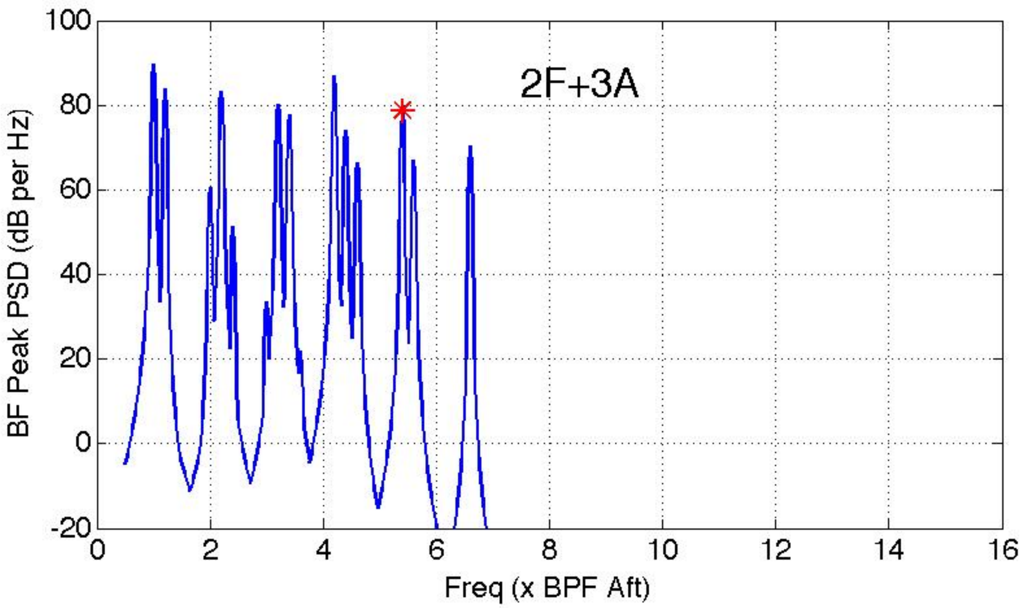

4821.5-4843.5 Hz
1.60 m
86.5 dB
87
dB
82


3F+A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
80
60
40
20
0
-20
0
2
4
6
8
10
12
14
16

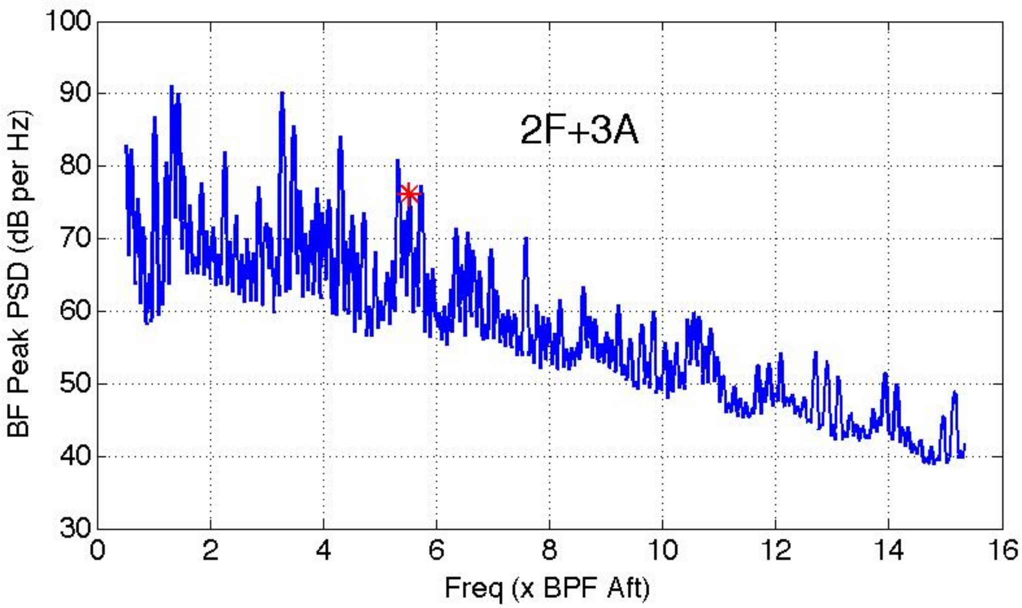

4923.5-4945.0 Hz
1.60 m
79.6 dB
80
dB
75

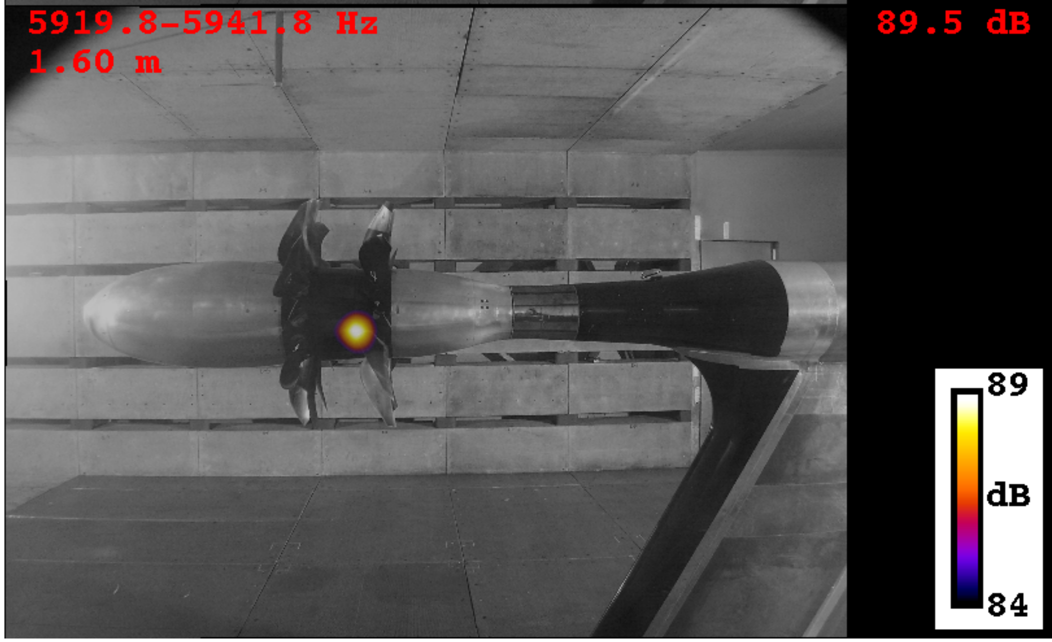

3F+A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
90
80
70
60
50
40
30
0
2
4
6
8
10
12
14
16

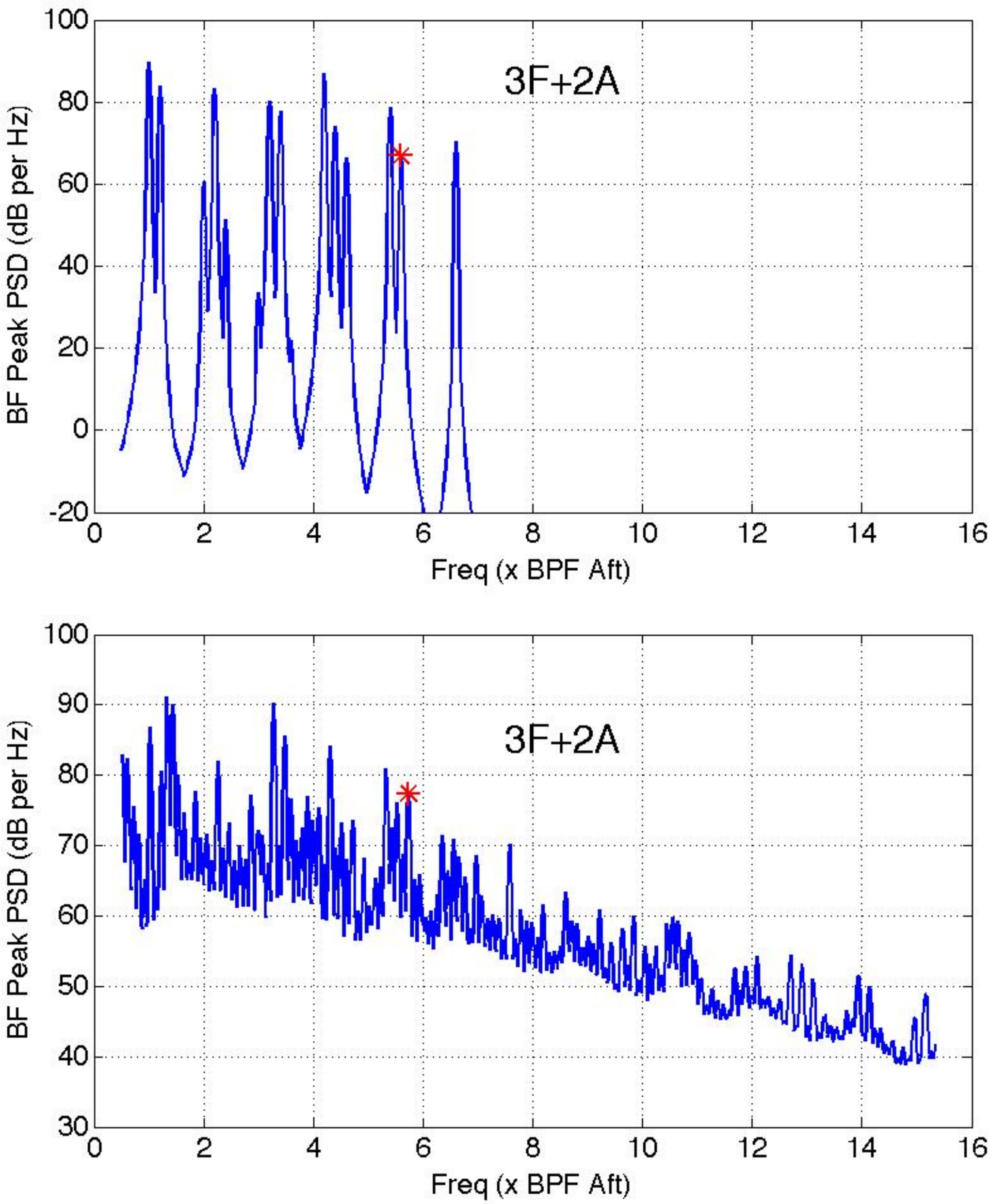

5041.2-5063.1 Hz
1.60 m
86.9 dB
87
dB
82

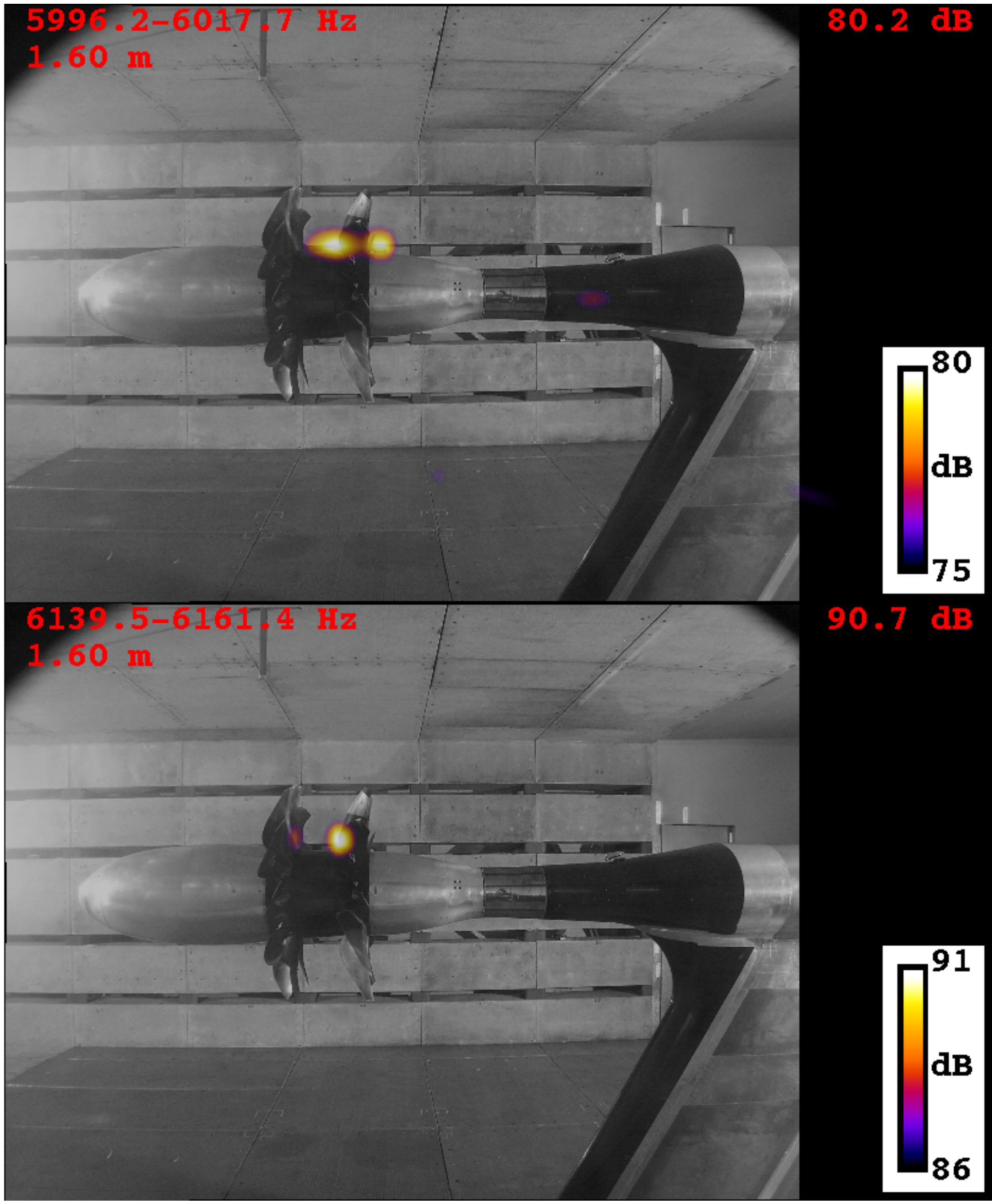

2F+3A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
80
60
40
20
0
-20
0
2
4
6
8
10
12
14
16

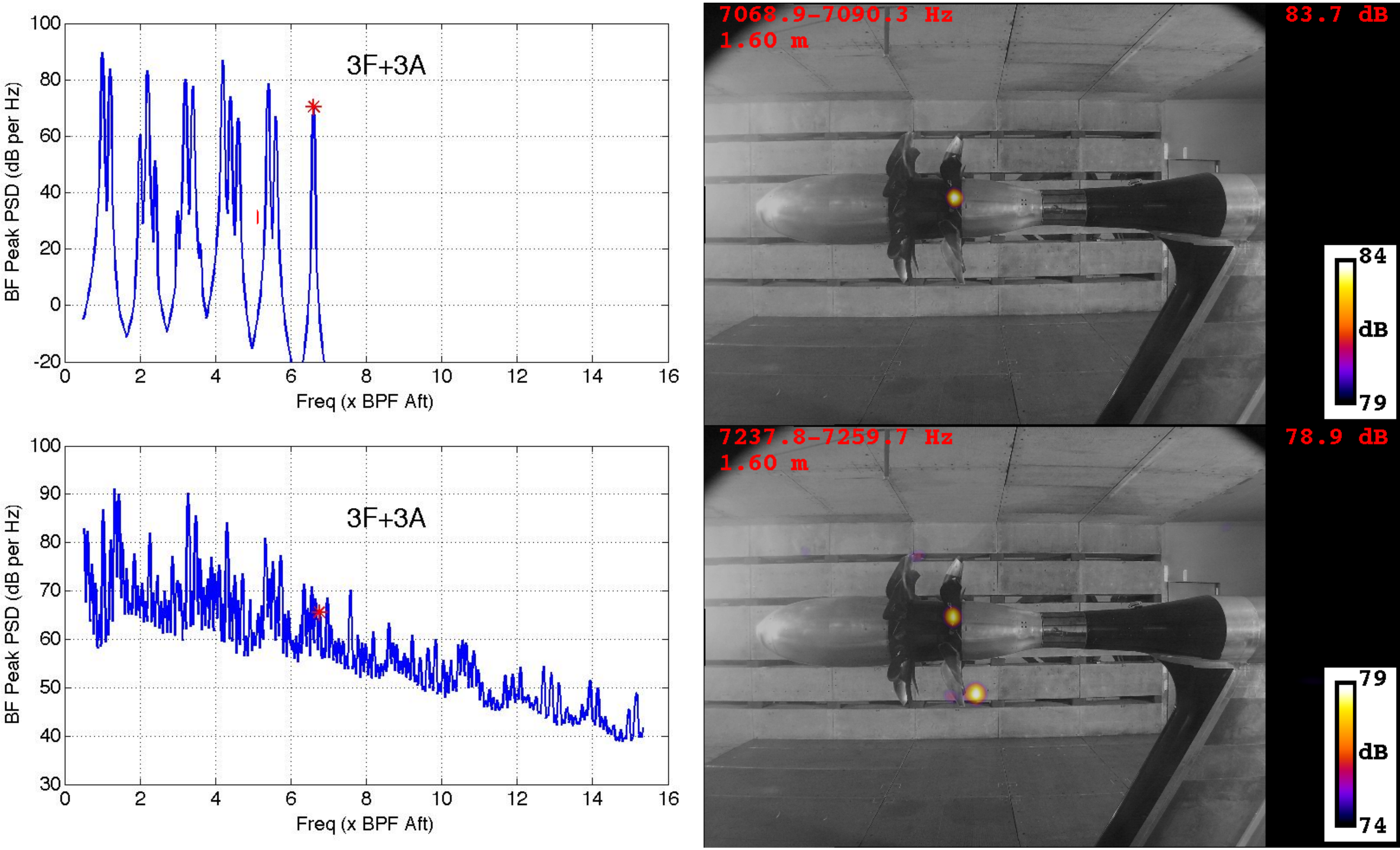

5781.7-5803.1 Hz
1.60 m
92.0 dB
92
dB
87


2F+3A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
90
80
70
60
50
40
30
0
2
4
6
8
10
12
14
16


5919.8-5941.8 Hz
1.60 m
89.5 dB
89
dB
84


100
80
60
40
20
0
-20
BF Peak PSD (dB per Hz)
3F+2A
0
2
4
6
8
10
12
14
16
Freq (x BPF Aft)
100
90
80
70
60
50
40
30
BF Peak PSD (dB per Hz)
3F+2A
Freq (x BPF Aft)


5996.2-6017.7 Hz
1.60 m
80.2 dB
80
dB
75
6139.5-6161.4 Hz
1.60 m
90.7 dB
91
dB
86


3F+3A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
3F+3A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
7068.9-7090.3 Hz
1.60 m
83.7 dB
84
dB
79
7237.8-7259.7 Hz
1.60 m
78.9 dB
79
dB
74

PREDICTION OF COUNTER-ROTATION PROPELLER NOISE

A.B. Parry*
Strathclyde University, Glasgow G1 1XH, U.K.

and

D.G. Crighton**
Cambridge University, Cambridge CB3 9EW, U.K.

In the case of counter-rotation propellers the pressure field is not locked to the rotors – as is the case with single-rotation propellers – but consists of an infinite number of spinning modes, each with a different mode phase speed. For each mode the radiation efficiency, represented by the Bessel function in (2.1) and (2.6), peaks near the radial station z^*, on a given blade, defined by

$$z^* = \frac{(n_1 B_1 - n_2 B_2)}{(n_1 B_1 M_{t_1} + n_2 B_2 M_{t_2})} \frac{(1 - M_x \cos\theta)}{\sin\theta}. \tag{2.11}$$

We refer to z^*, as in previous work, as the "Mach radius", and emphasise the dependence of z^* not just on θ, but also on n_1 and n_2.

Mach Radius Equation
for an observer at the location of the phased array

$$z^{*} = \frac{n_1 B_1 - n_2 B_2}{n_1 B_1 M_{t1} + n_2 B_2 M_{t2}}$$

B_1=12, number of blades in front rotor
B_2=10, number of blades in aft rotor
M_t=blade tip rotational Mach number
n=harmonic index
1, front rotor
2, aft rotor

Mach Radius Equation
for an observer at the location of the phased array
for F, 2F, 3F, etc.

$$z^* = \frac{1}{M_{t1}}$$

Mach Radius Equation
for an observer at the location of the phased array
for A, 2A, 3A, etc.

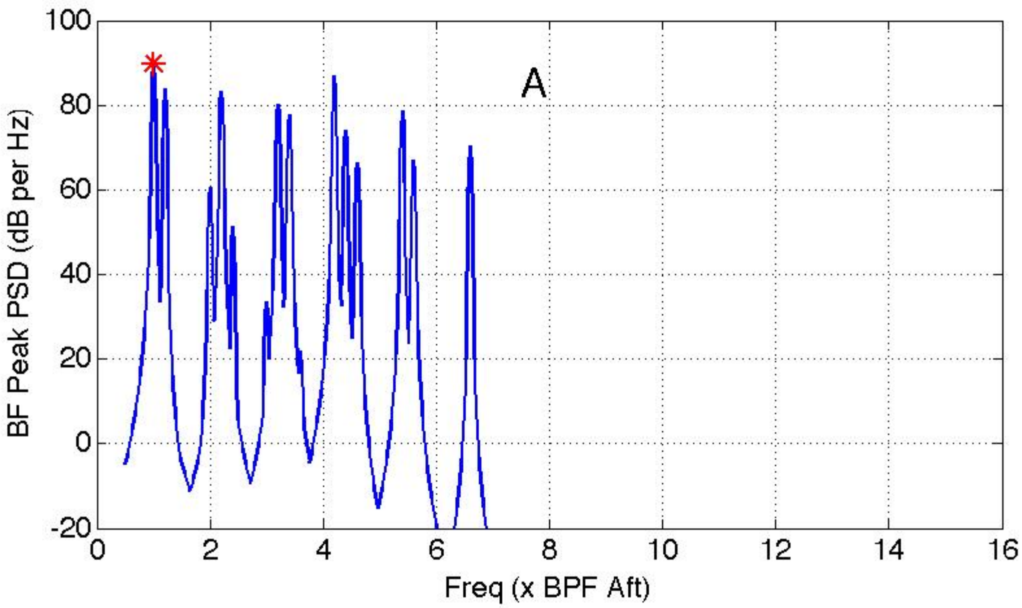
$$z^* = \frac{-1}{M_{t2}}$$

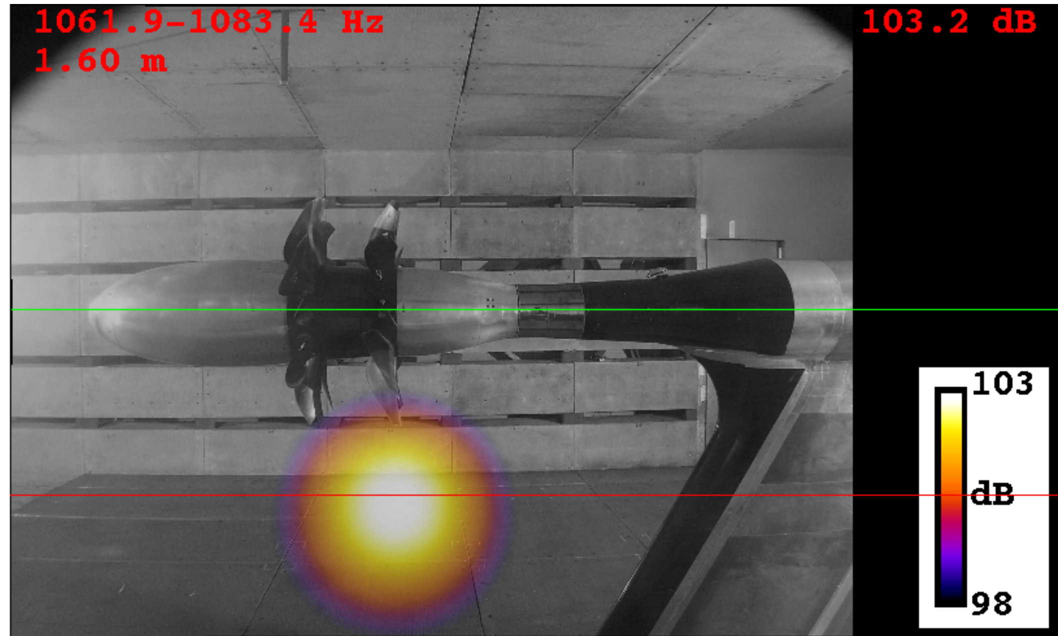
Mach Radius Equation
for an observer at the location of the phased array
for interaction tones

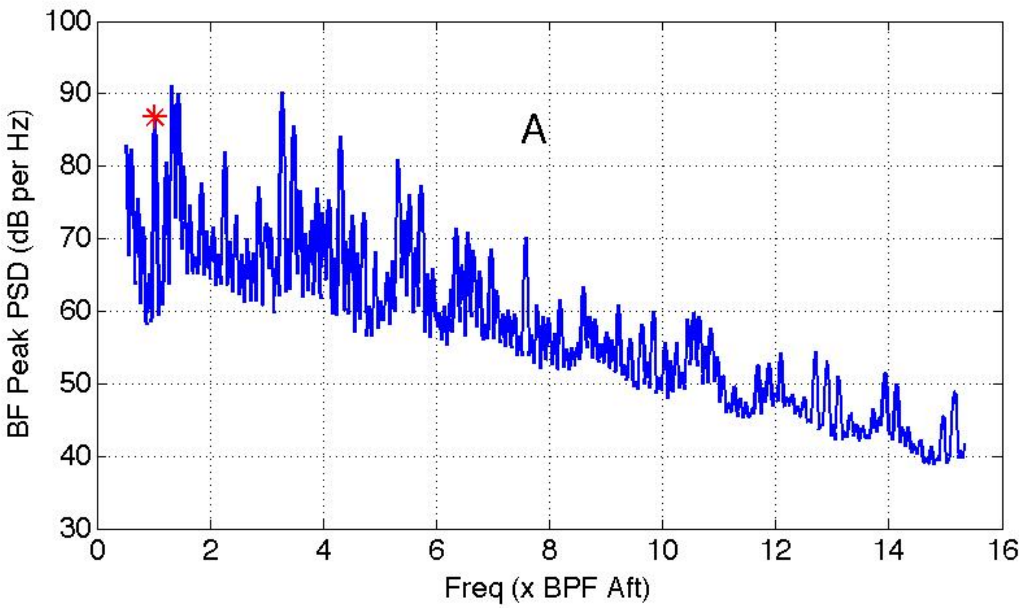
$$z^* = \frac{n_1 B_1 - n_2 B_2}{n_1 B_1 M_{t1} + n_2 B_2 M_{t2}}$$

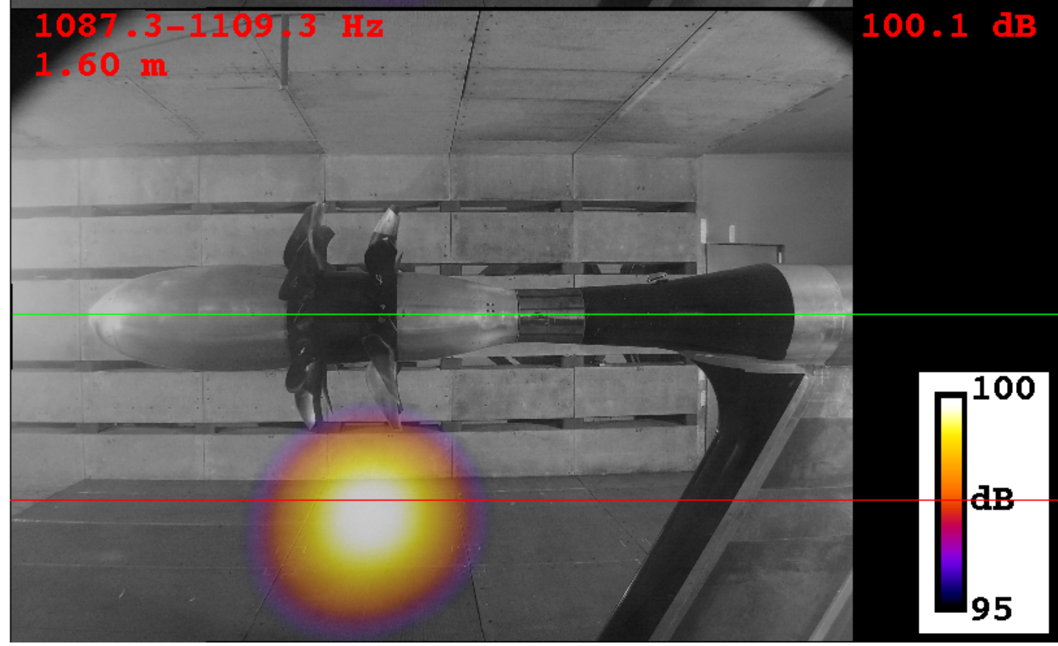
For 3F+A tone
$n_1=3$
$n_2=1$

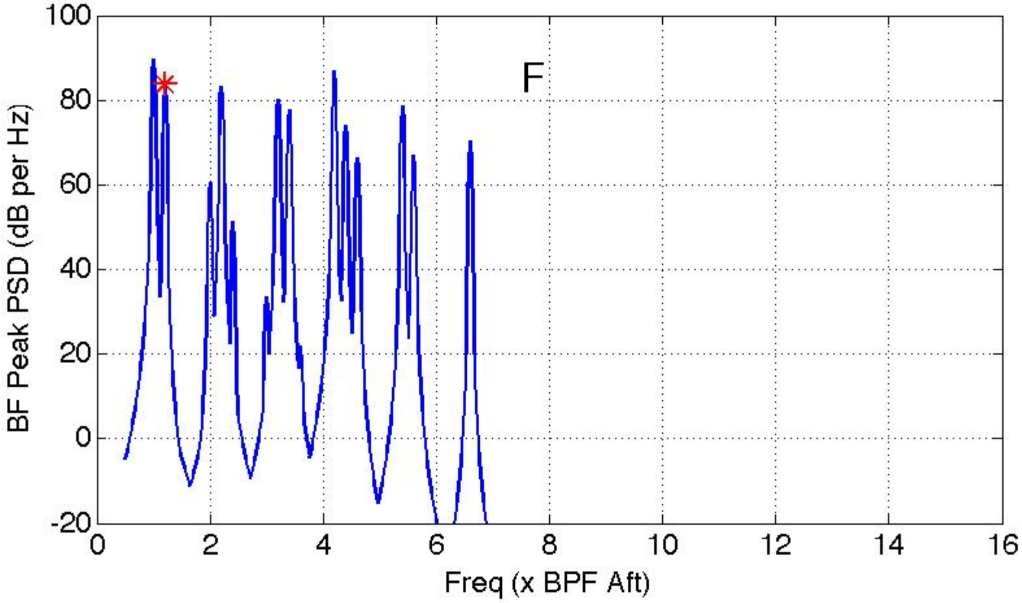
For 3F+2A tone
$n_1=3$
$n_2=2$

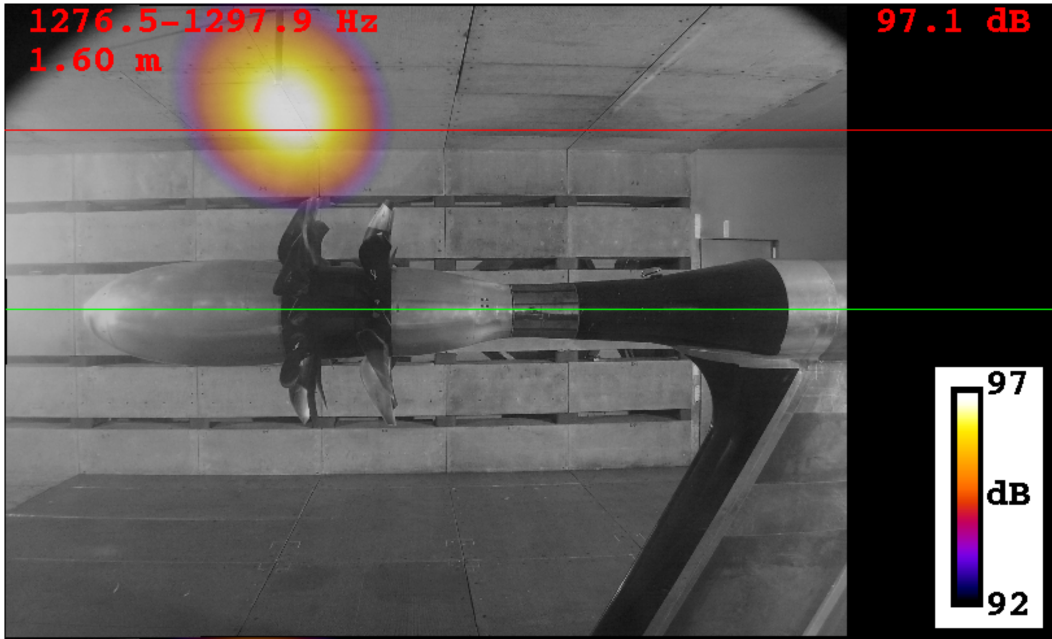

A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)

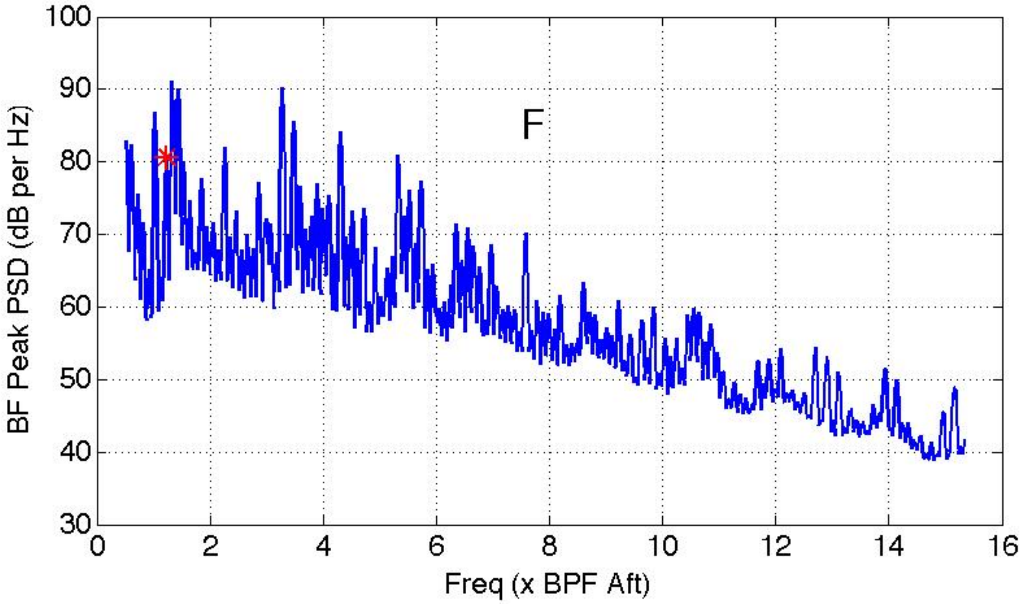

1061.9–1083.4 Hz
1.60 m
103.2 dB
103
dB
98

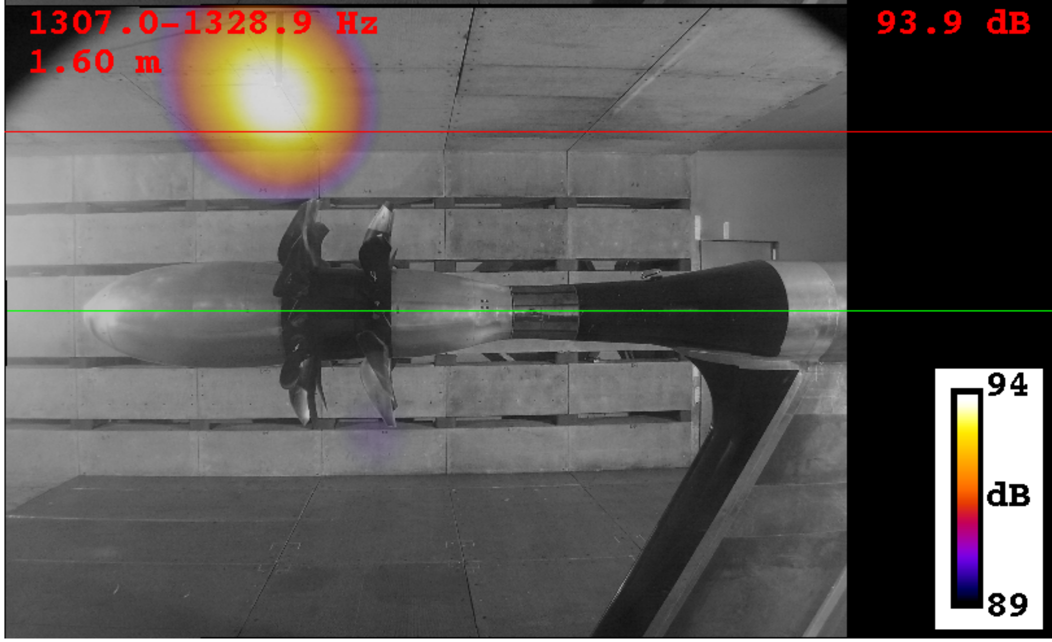

A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)

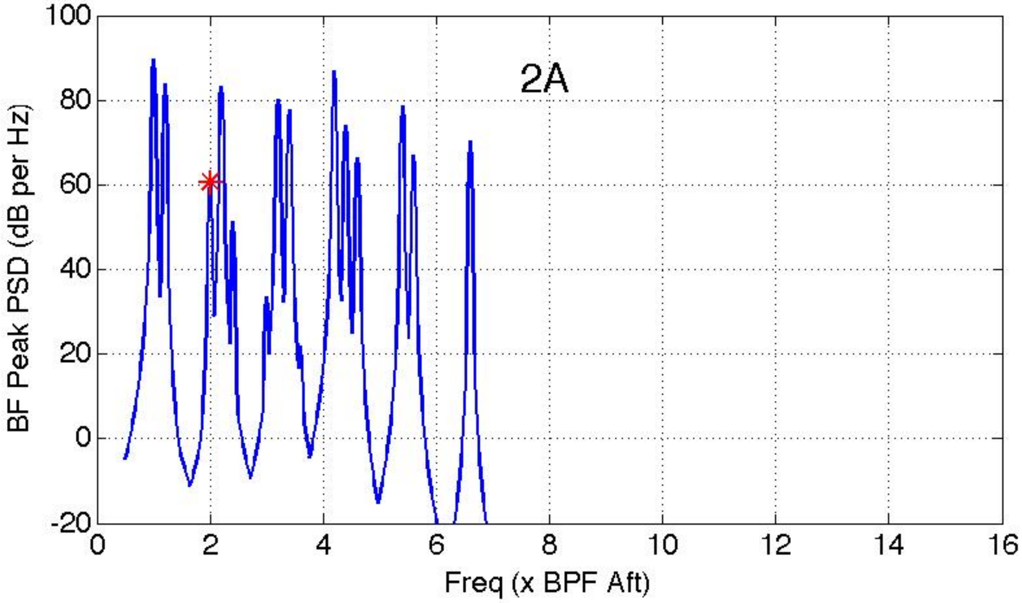

1087.3–1109.3 Hz
1.60 m
100.1 dB
100
dB
95


F
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)

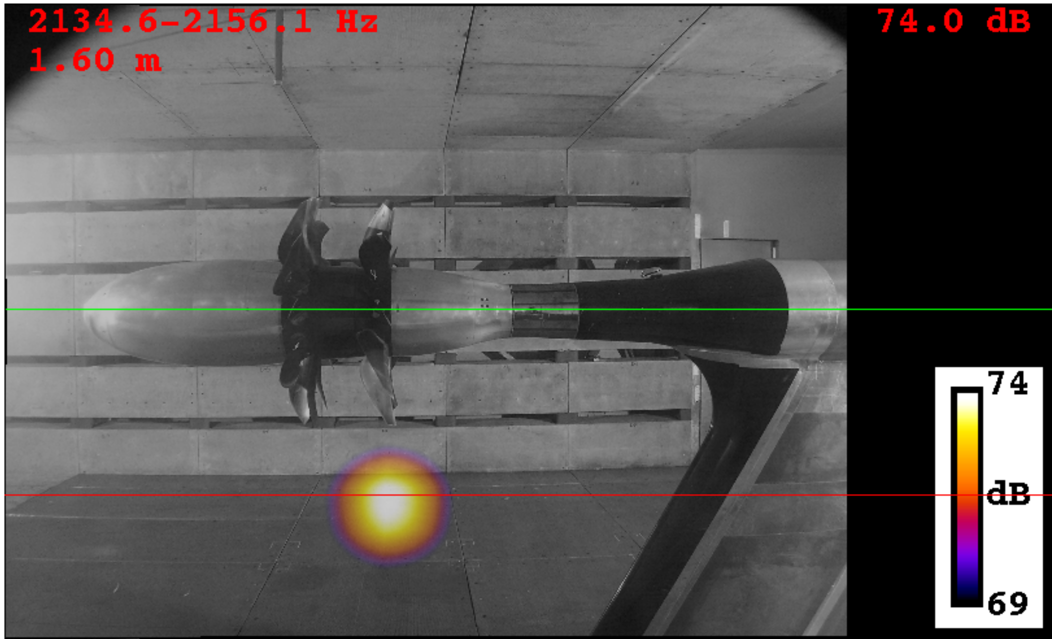

1276.5-1297.9 Hz
1.60 m
97.1 dB
97
dB
92


F
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)

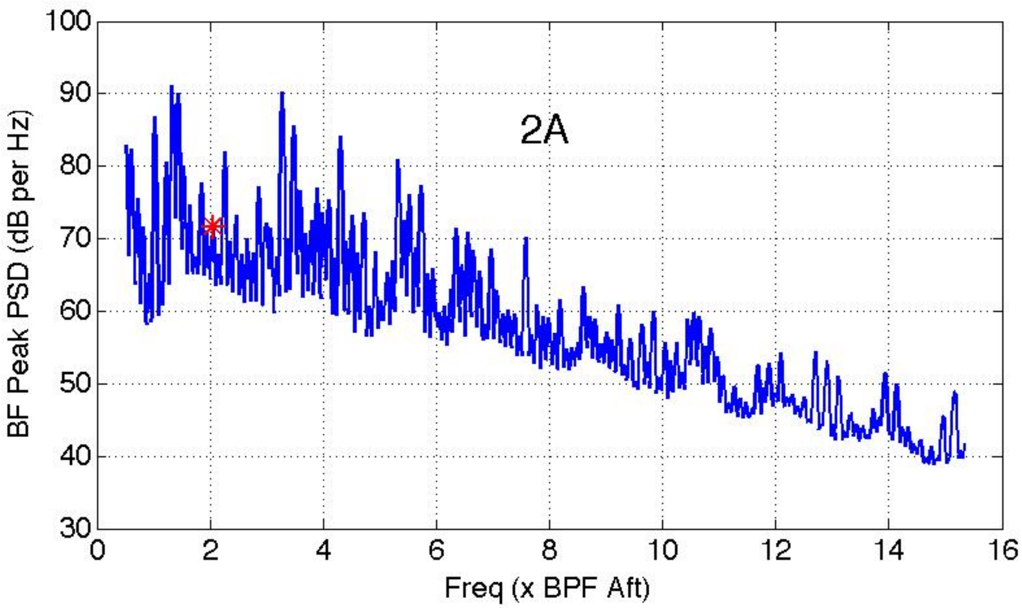

1307.0-1328.9 Hz
1.60 m
93.9 dB
94
dB
89



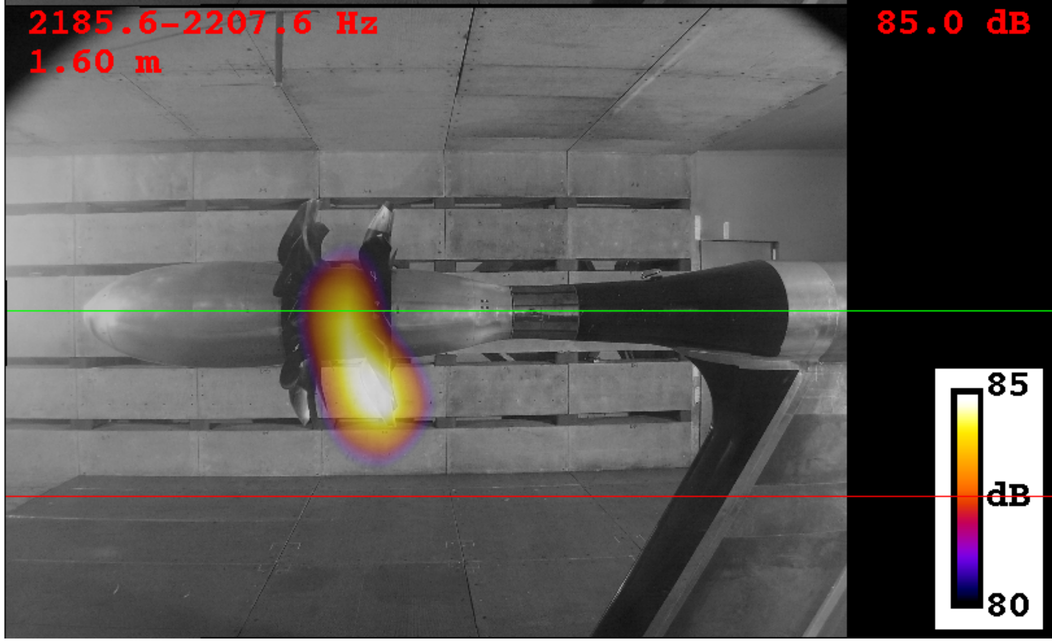
100
80
60
40
20
0
-20
0 2 4 6 8 10 12 14 16
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
2A



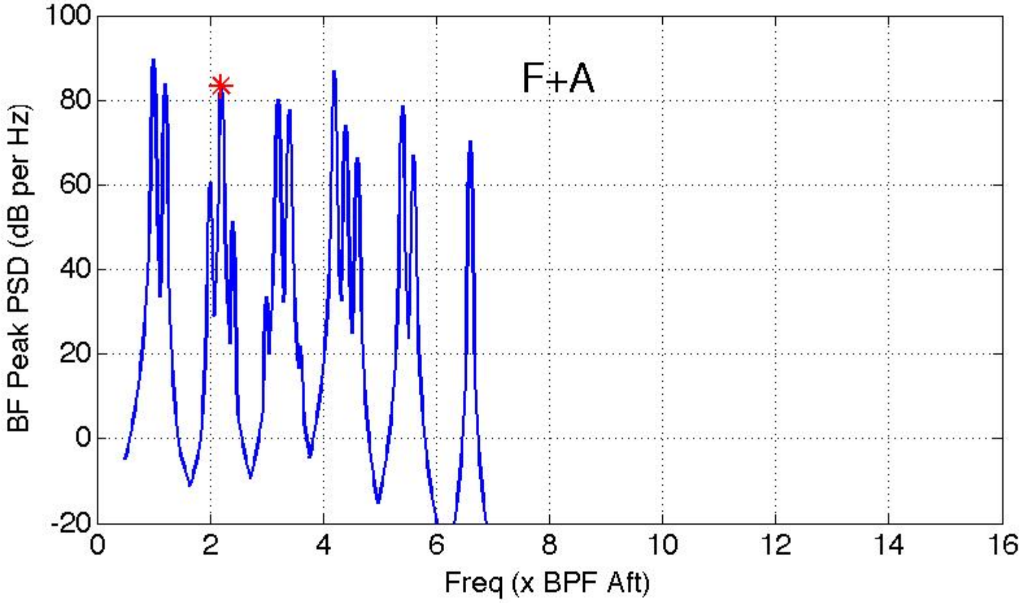
2134.6-2156.1 Hz
1.60 m
74.0 dB
74
dB
69



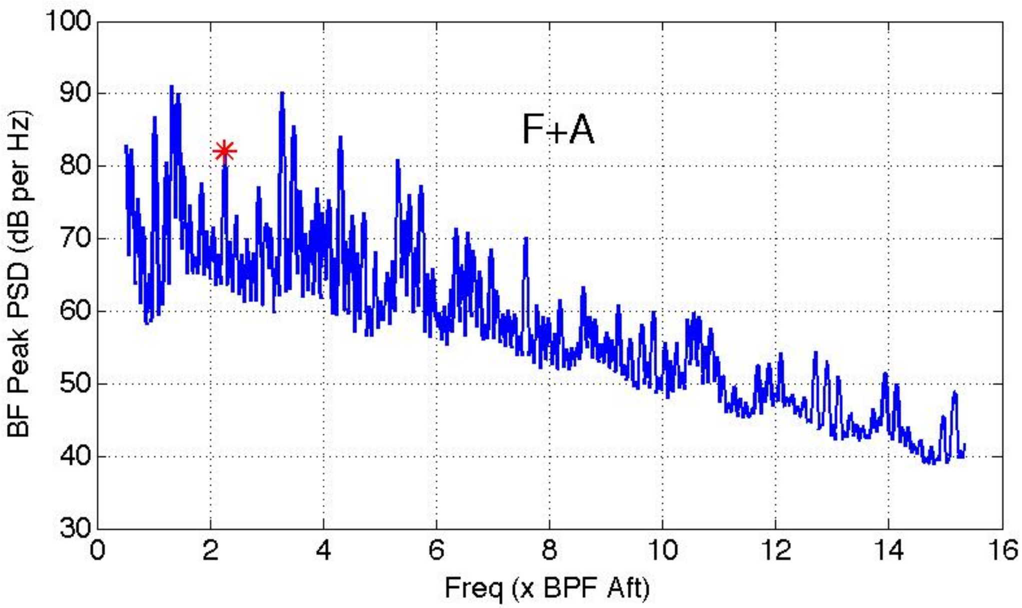
100
90
80
70
60
50
40
30
0 2 4 6 8 10 12 14 16
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
2A



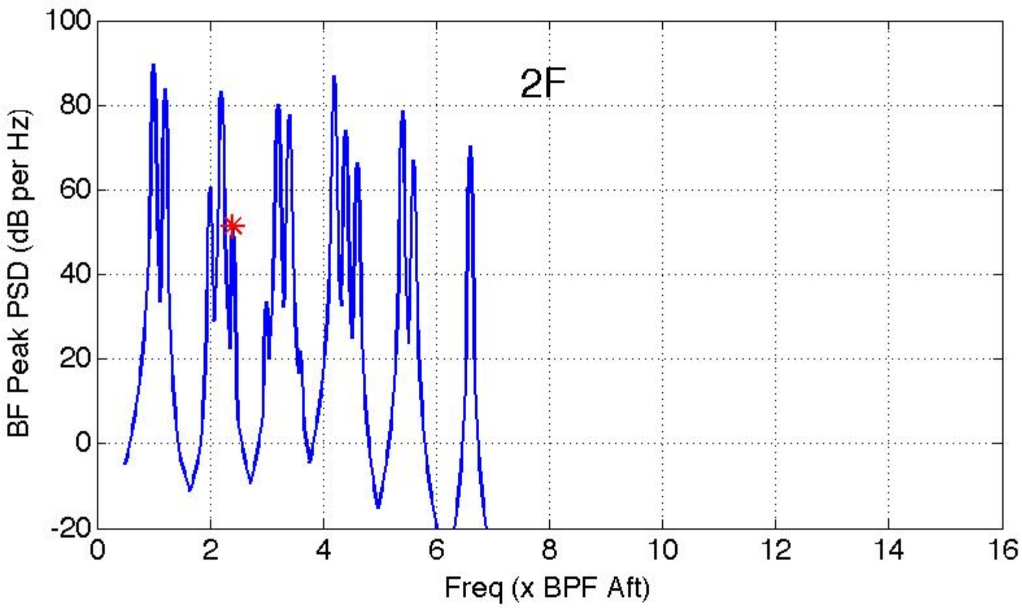
2185.6-2207.6 Hz
1.60 m
85.0 dB
85
dB
80

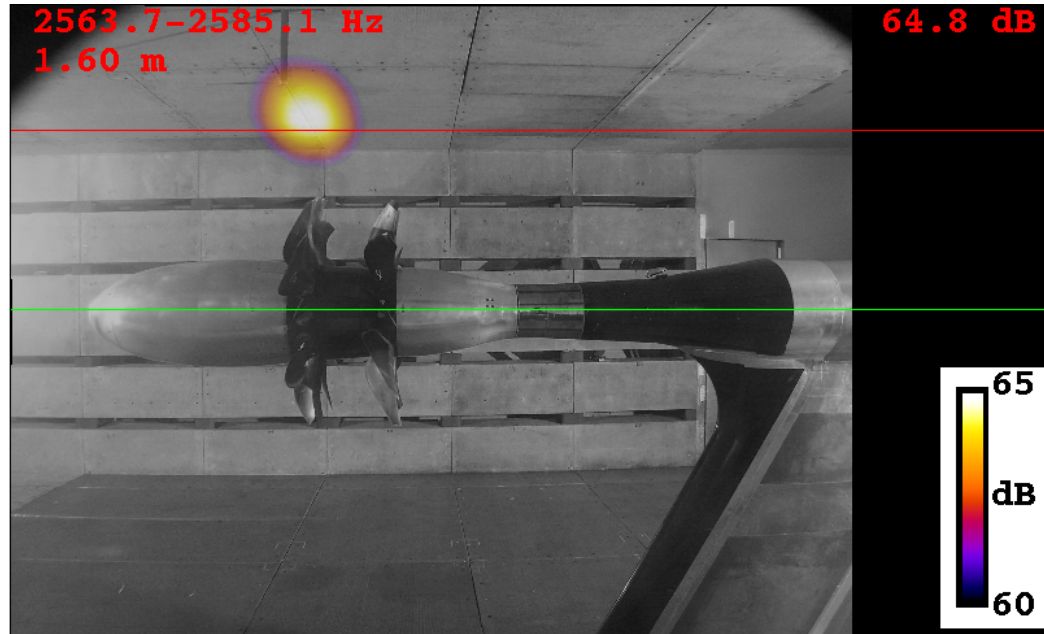

F+A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
80
60
40
20
0
-20
0
2
4
6
8
10
12
14
16

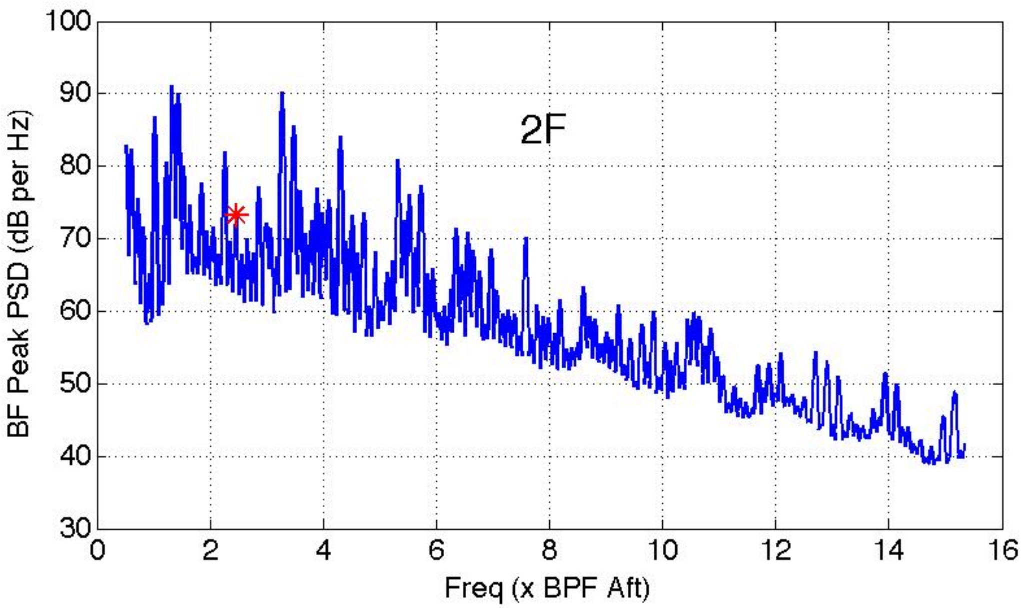

2349.1-2370.6 Hz
1.60 m
96.7 dB
97
dB
92

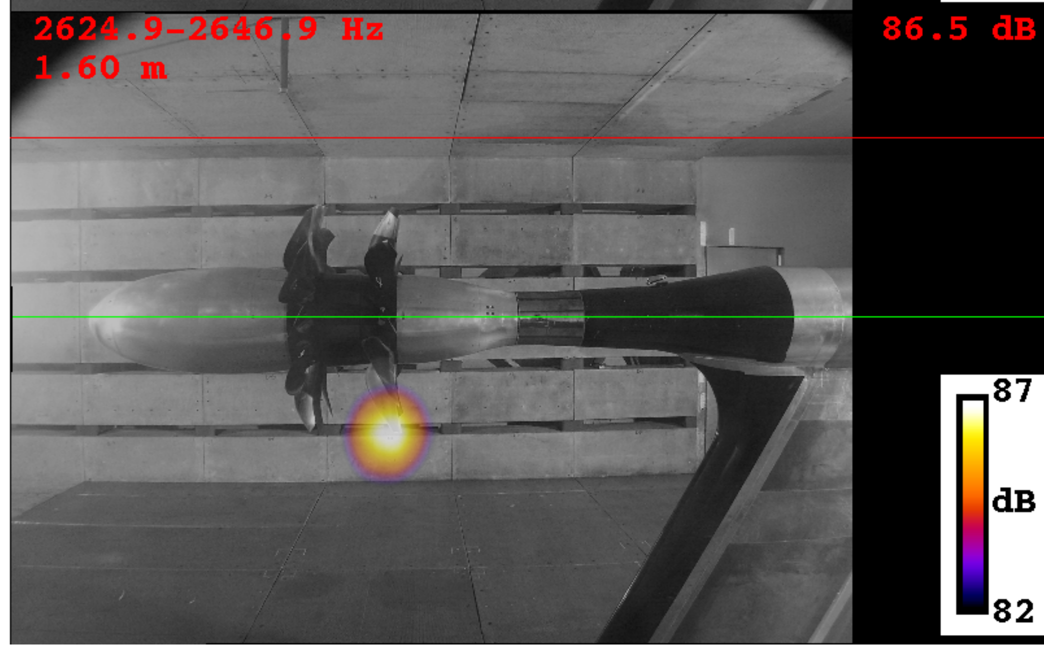

F+A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
90
80
70
60
50
40
30
0
2
4
6
8
10
12
14
16

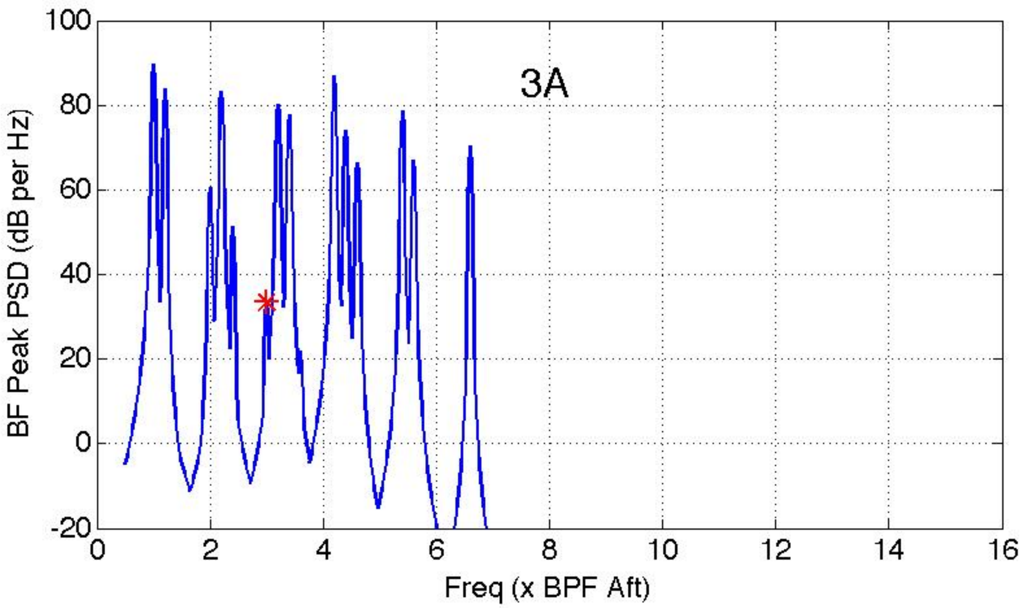

2405.3-2427.2 Hz
1.60 m
95.4 dB
95
dB
90

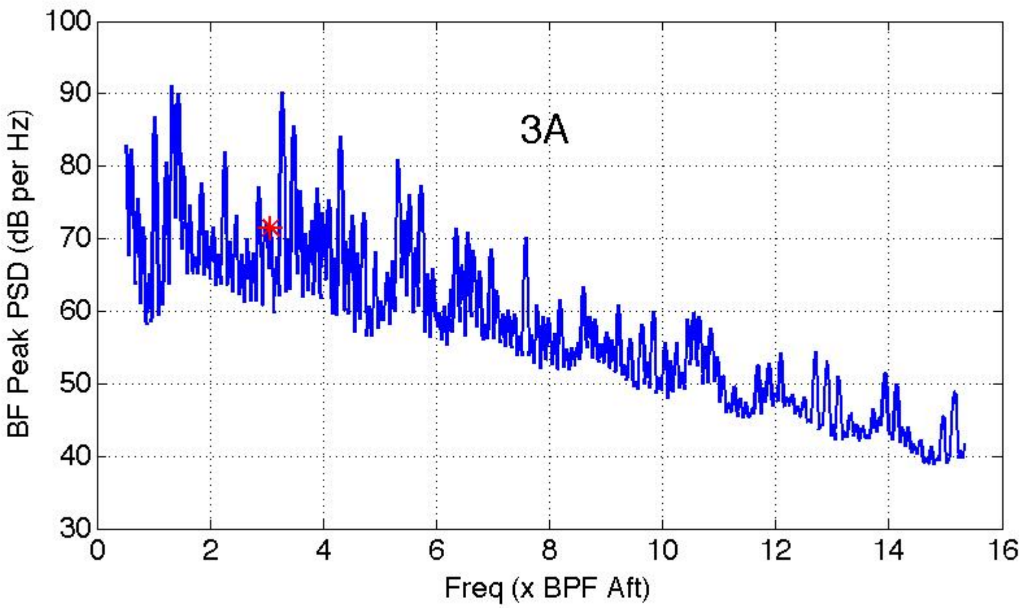

2F
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
80
60
40
20
0
-20
0
2
4
6
8
10
12
14
16

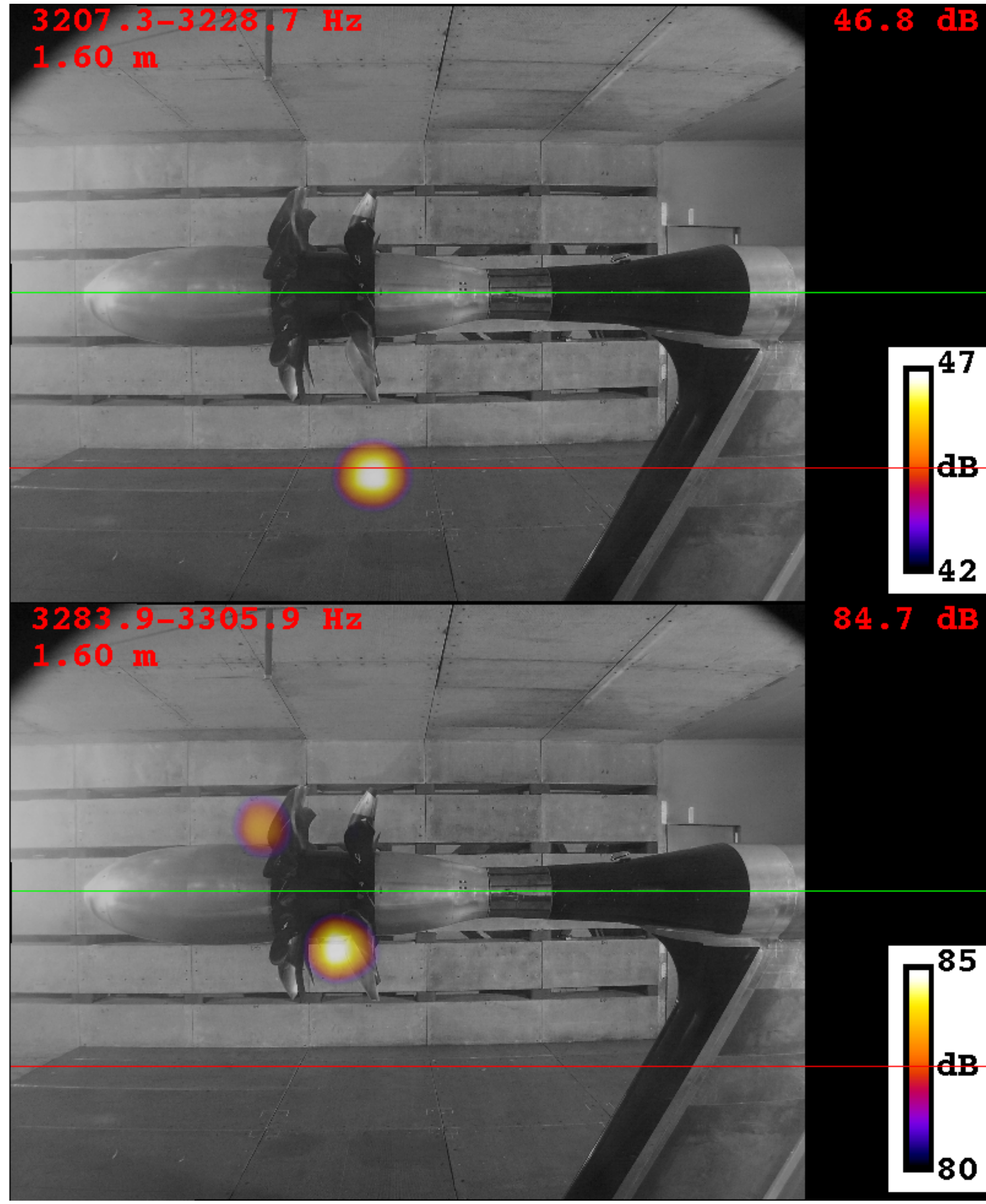

2563.7-2585.1 Hz
1.60 m
64.8 dB
65
dB
60

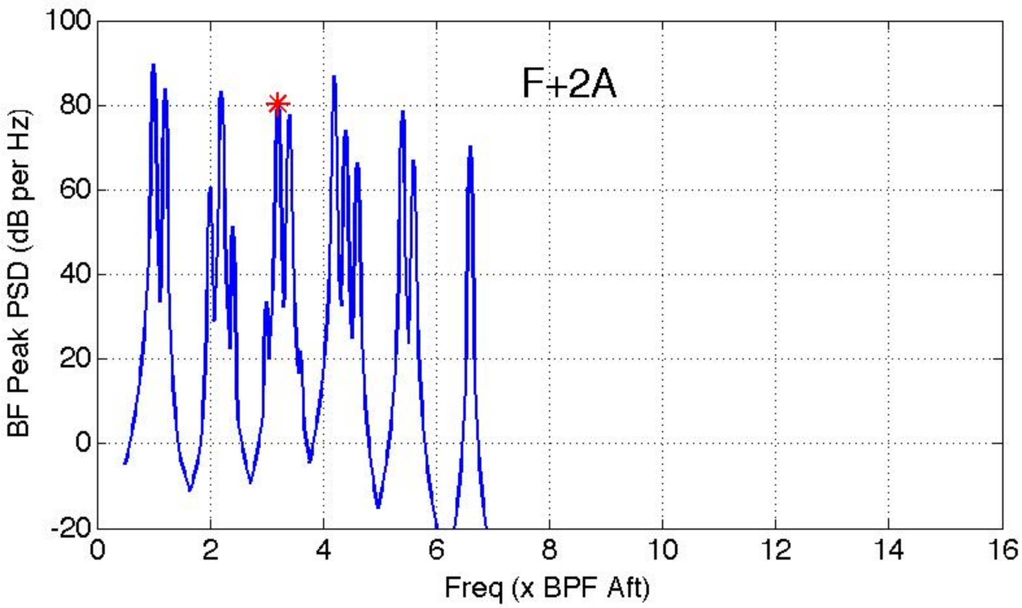

2F
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
90
80
70
60
50
40
30
0
2
4
6
8
10
12
14
16


2624.9-2646.9 Hz
1.60 m
86.5 dB
87
dB
82

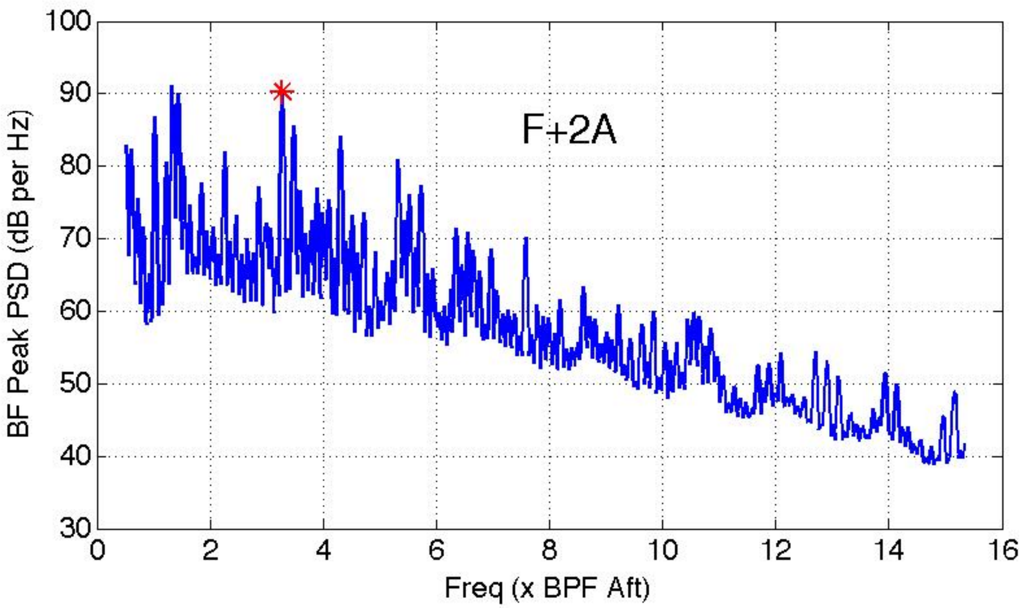

3A
BF Peak PSD (dB per Hz)
100
80
60
40
20
0
-20
0
2
4
6
8
10
12
14
16
Freq (x BPF Aft)


3A
BF Peak PSD (dB per Hz)
100
90
80
70
60
50
40
30
0
2
4
6
8
10
12
14
16
Freq (x BPF Aft)

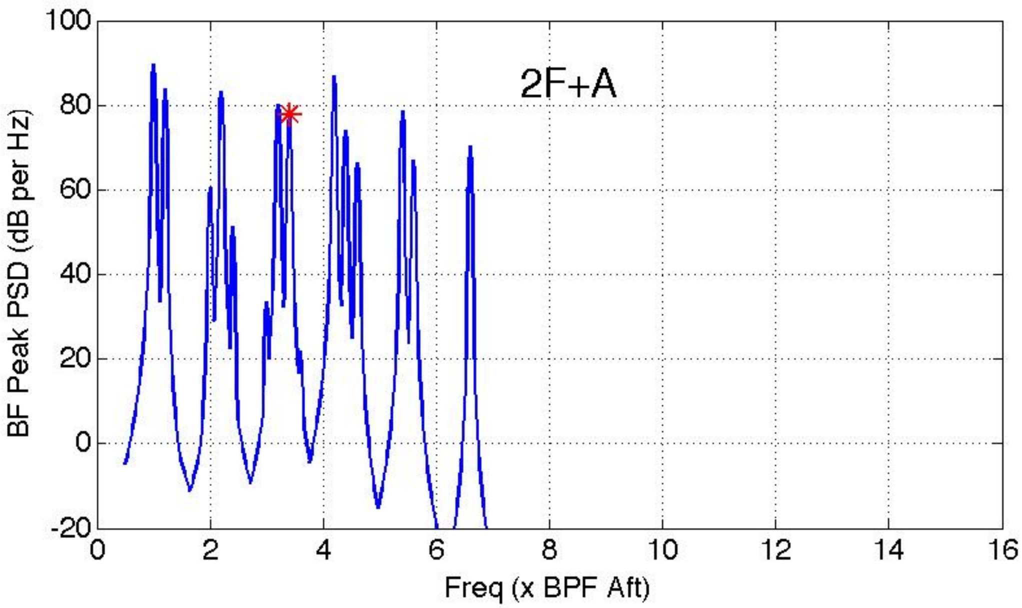

3207.3-3228.7 Hz
1.60 m
46.8 dB
47
dB
42
3283.9-3305.9 Hz
1.60 m
84.7 dB
85
dB
80

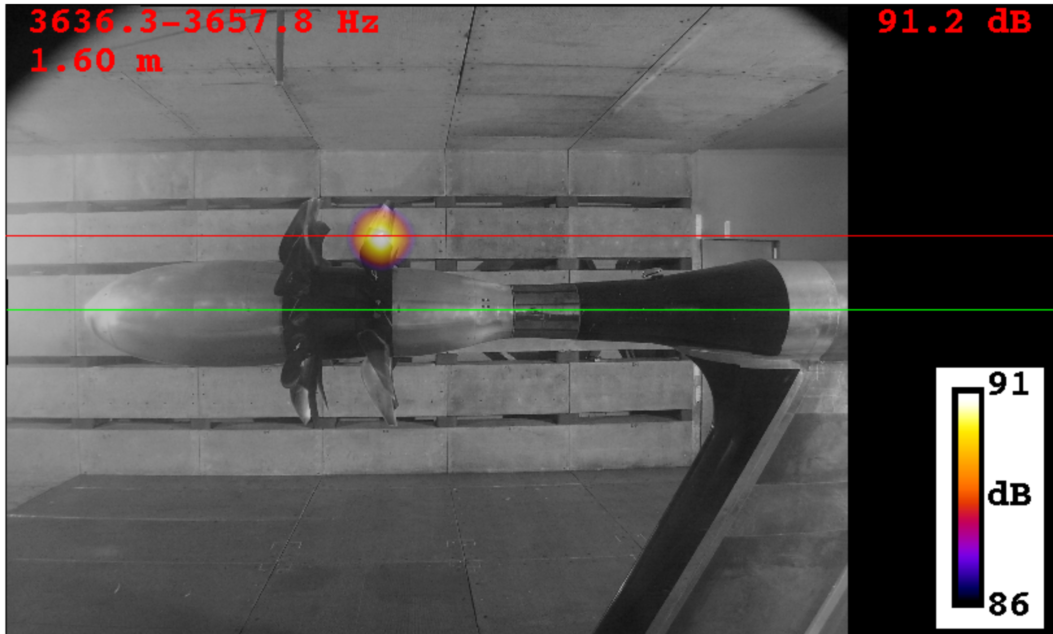

F+2A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
80
60
40
20
0
-20
0
2
4
6
8
10
12
14
16

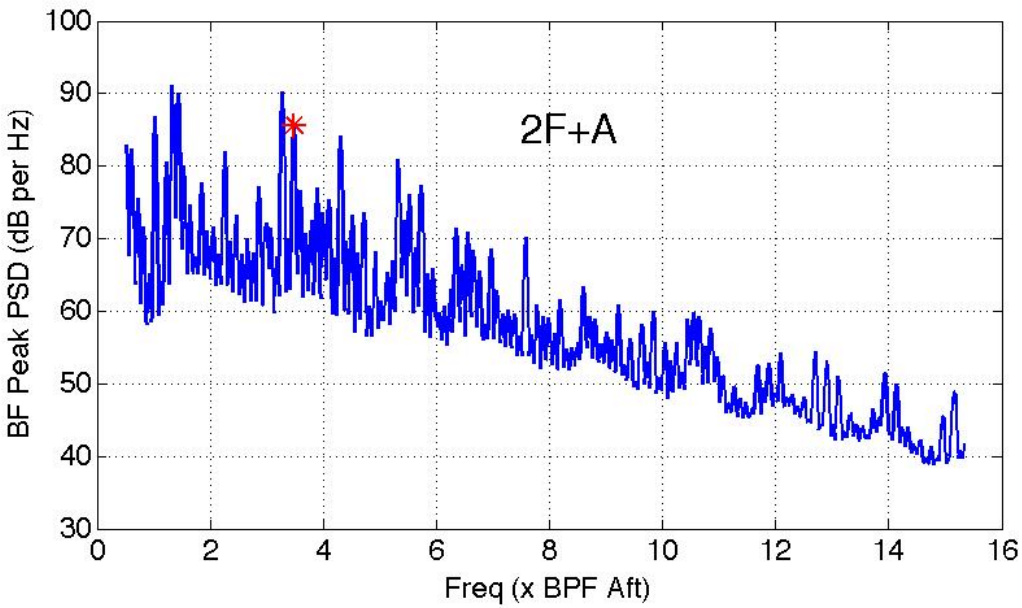

3421.8-3443.3 Hz
1.60 m
93.6 dB
94
dB
89

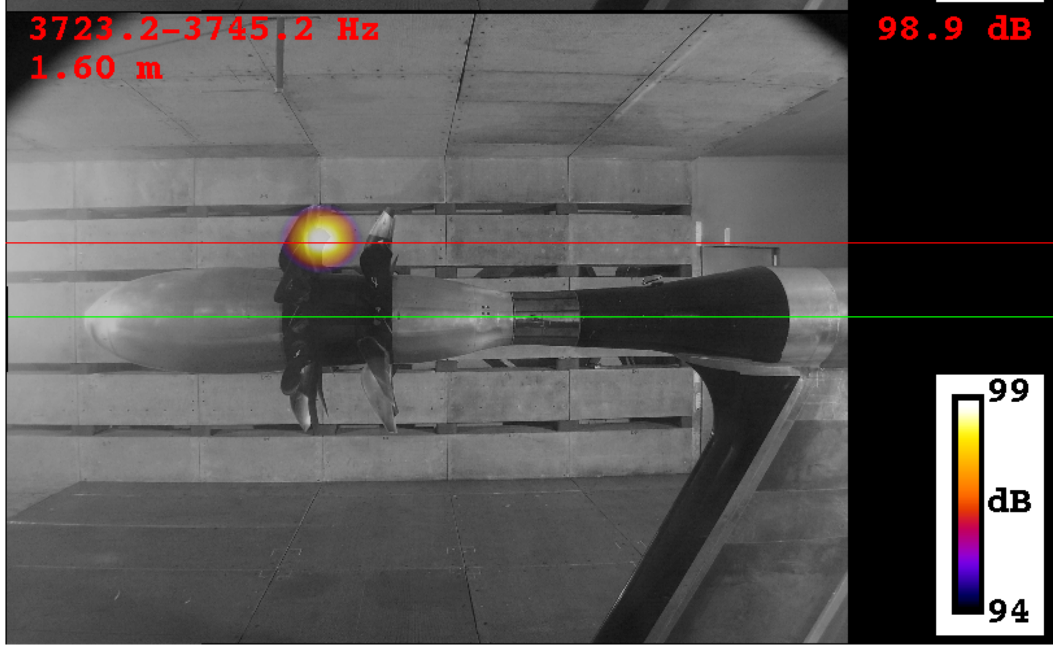

F+2A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
90
80
70
60
50
40
30
0
2
4
6
8
10
12
14
16

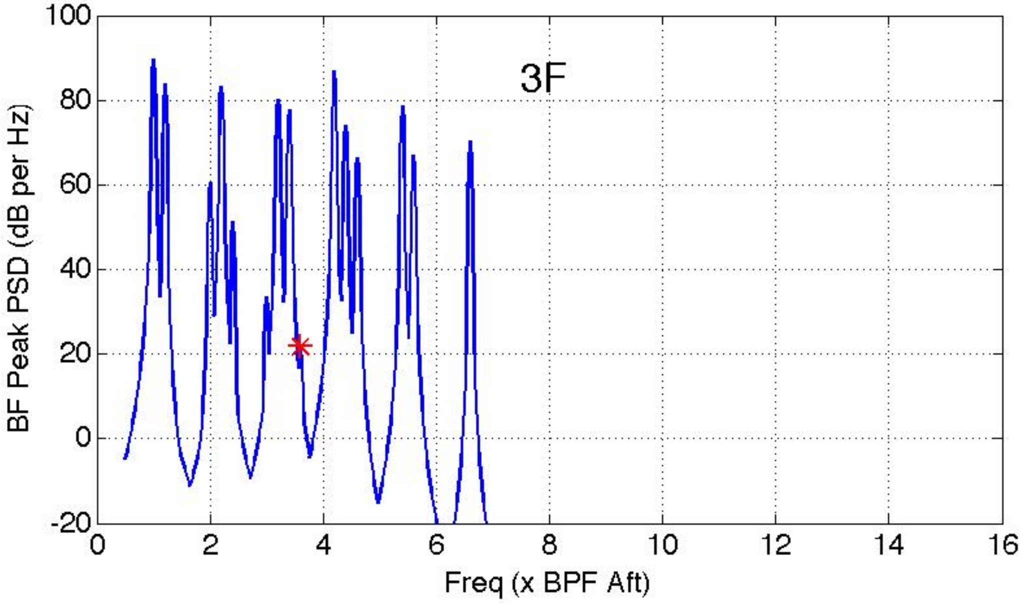

3503.6-3525.5 Hz
1.60 m
103.5 dB
104
dB
99

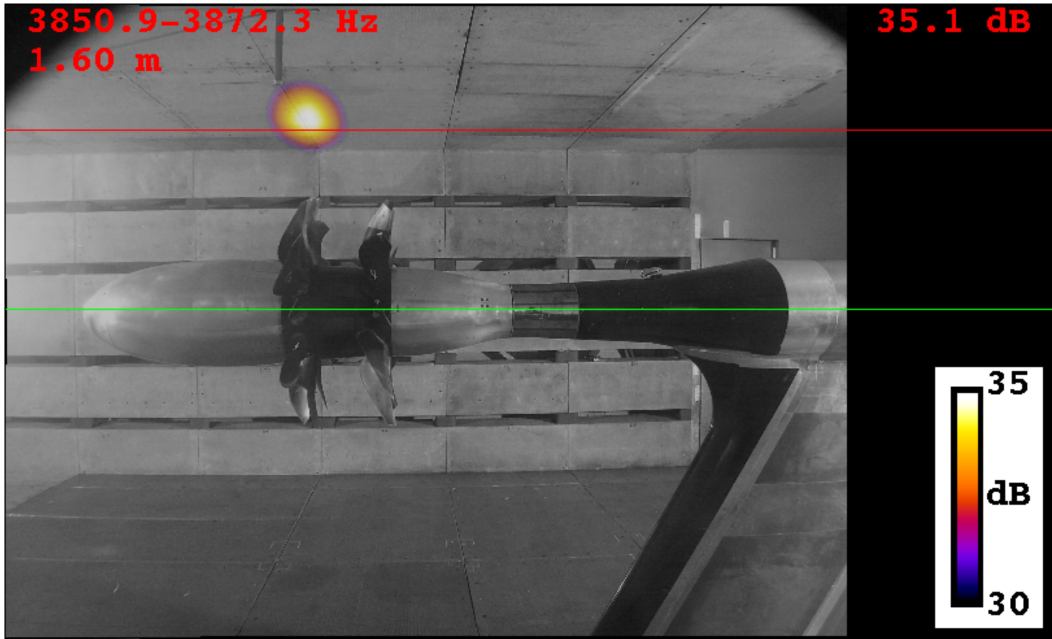

2F+A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
80
60
40
20
0
-20
0
2
4
6
8
10
12
14
16

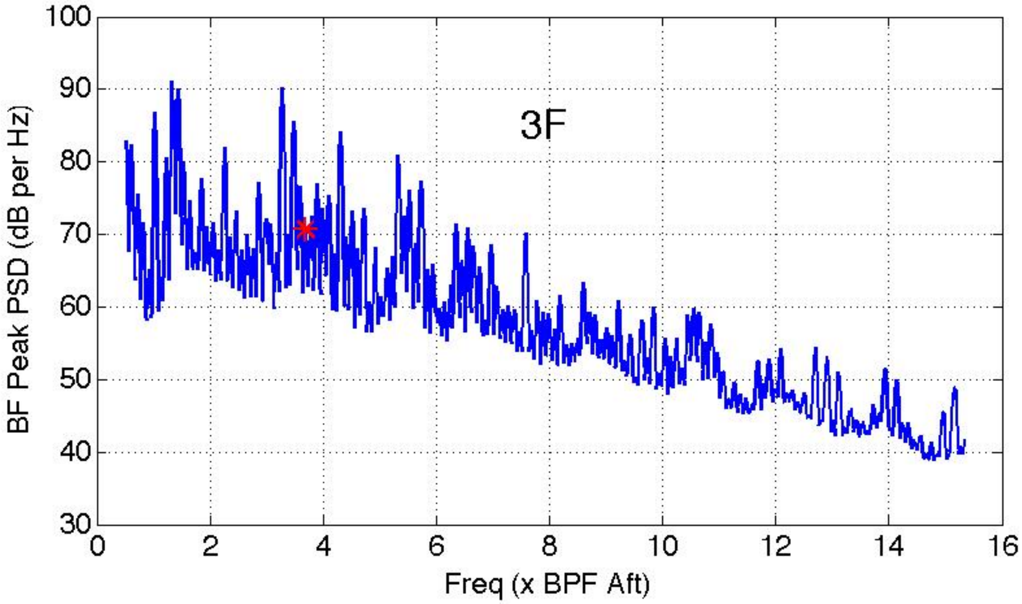

3636.3-3657.8 Hz
1.60 m
91.2 dB
91
dB
86

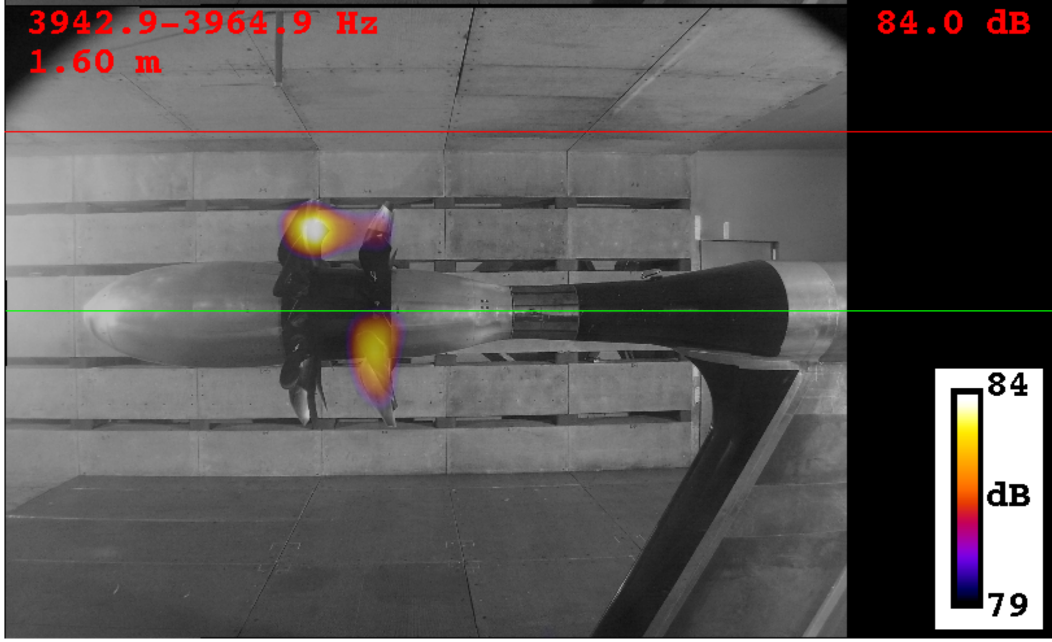

2F+A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
90
80
70
60
50
40
30
0
2
4
6
8
10
12
14
16

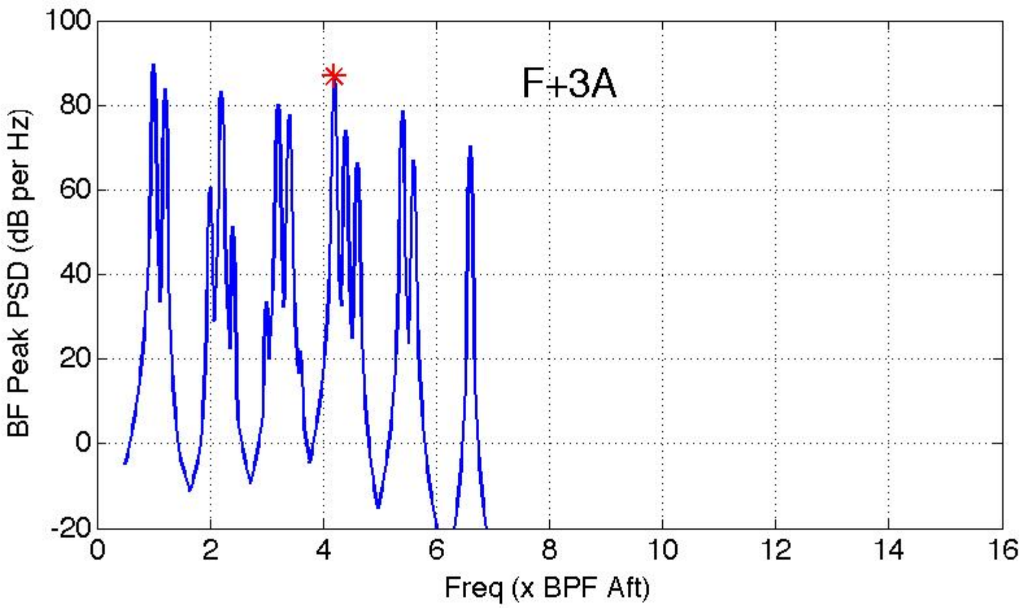

3723.2-3745.2 Hz
1.60 m
98.9 dB
99
dB
94


3F
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)

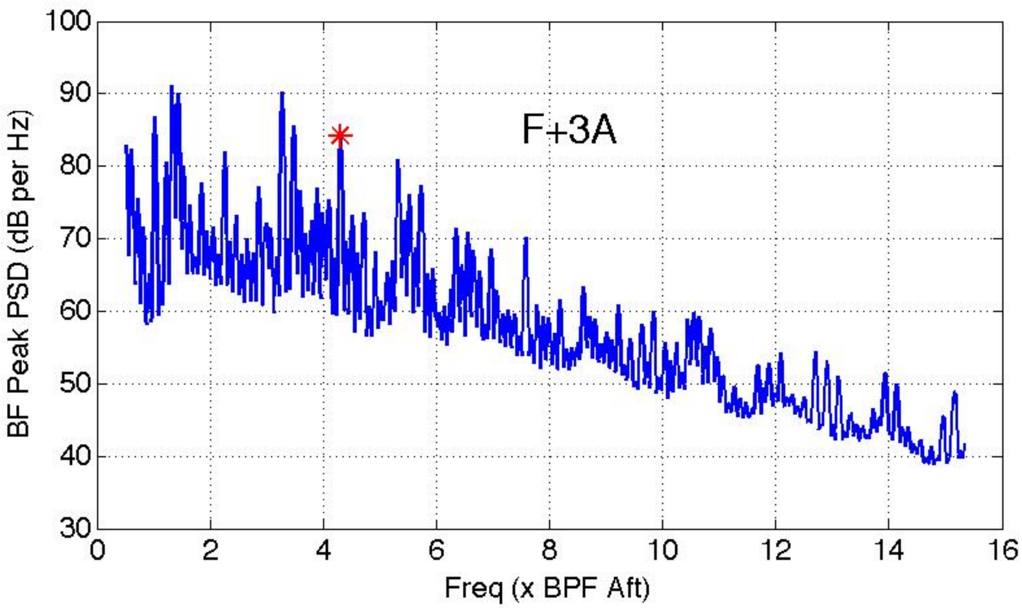

3850.9-3872.3 Hz
1.60 m
35.1 dB
35
dB
30


3F
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)

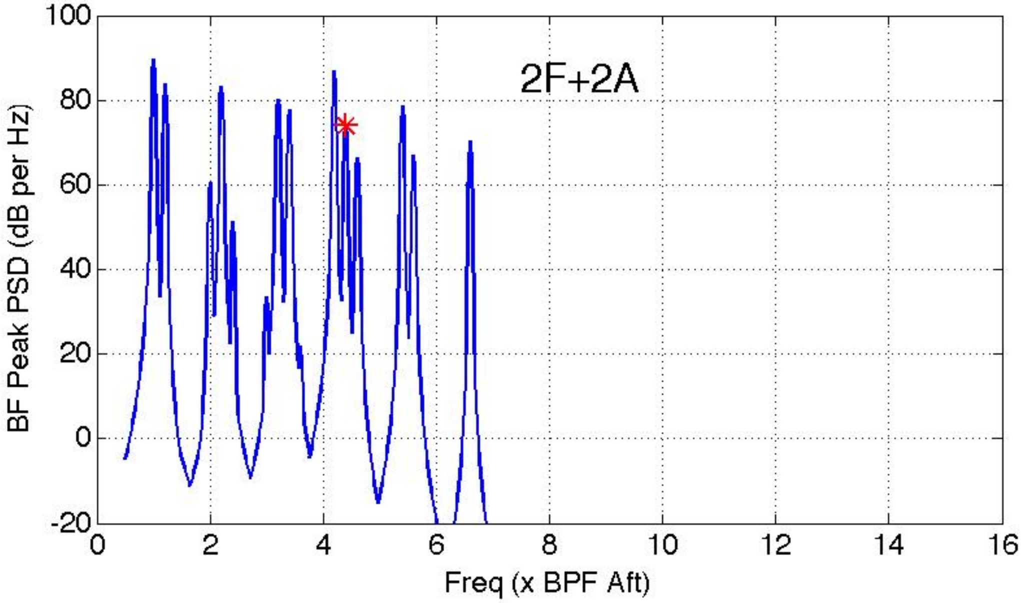

3942.9-3964.9 Hz
1.60 m
84.0 dB
84
dB
79

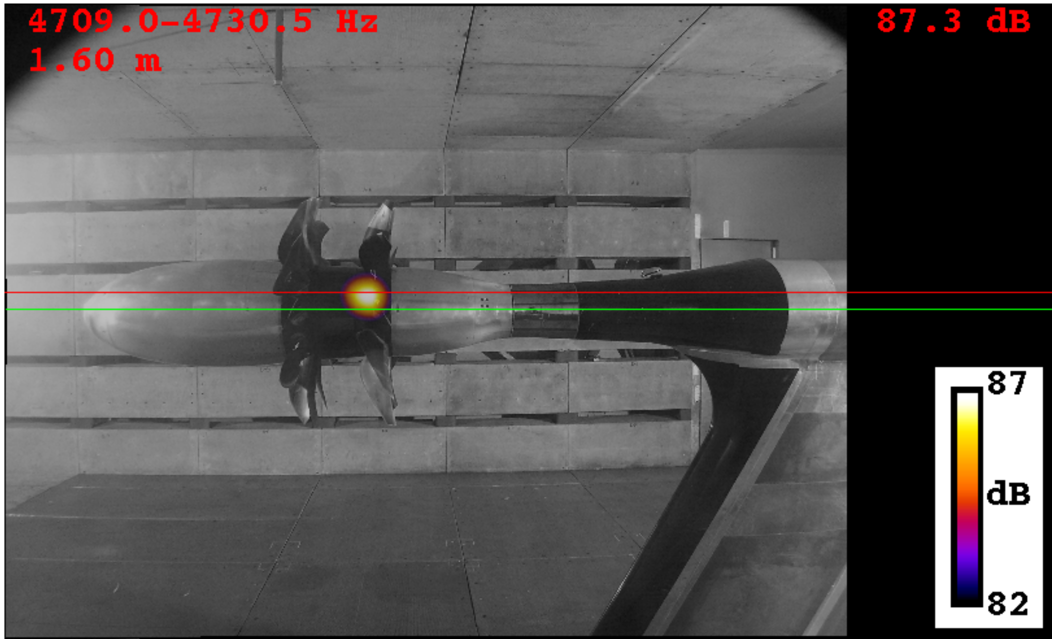

F+3A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
80
60
40
20
0
-20
0
2
4
6
8
10
12
14
16

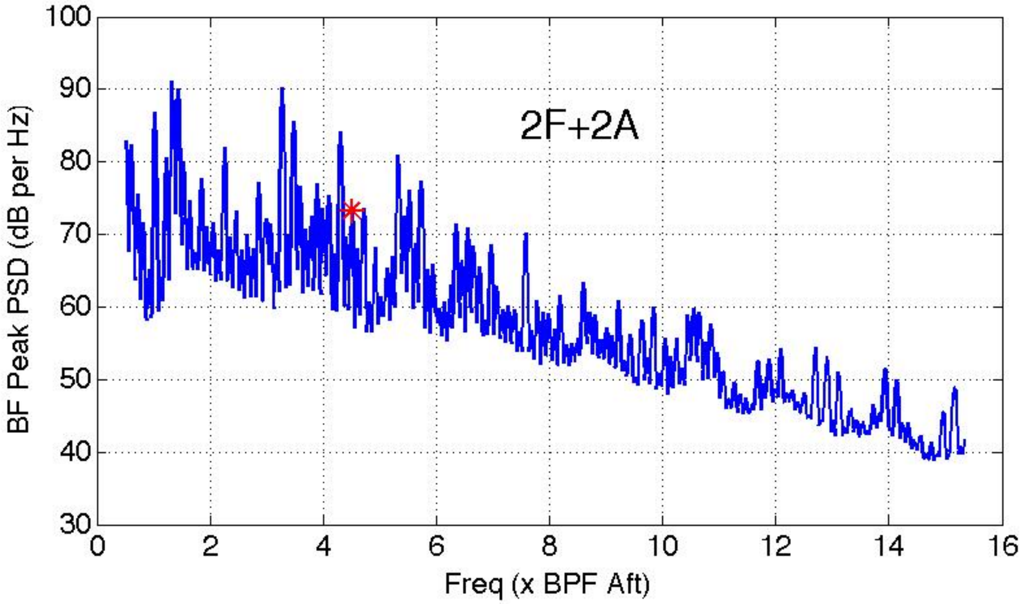

4494.5-4515.9 Hz
1.60 m
100.1 dB
100
dB
95

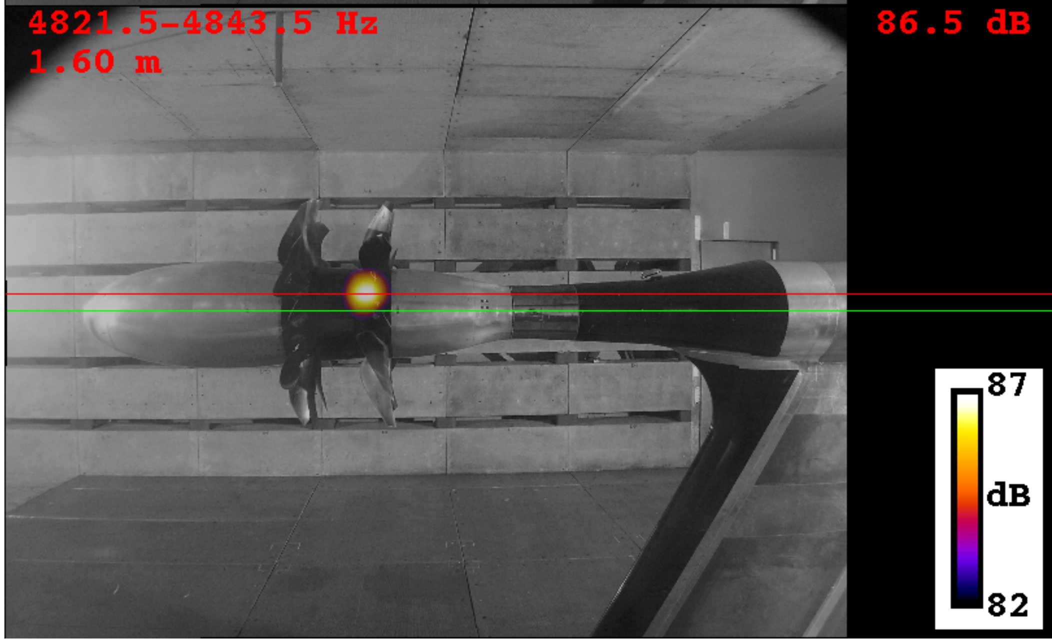

F+3A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
90
80
70
60
50
40
30
0
2
4
6
8
10
12
14
16

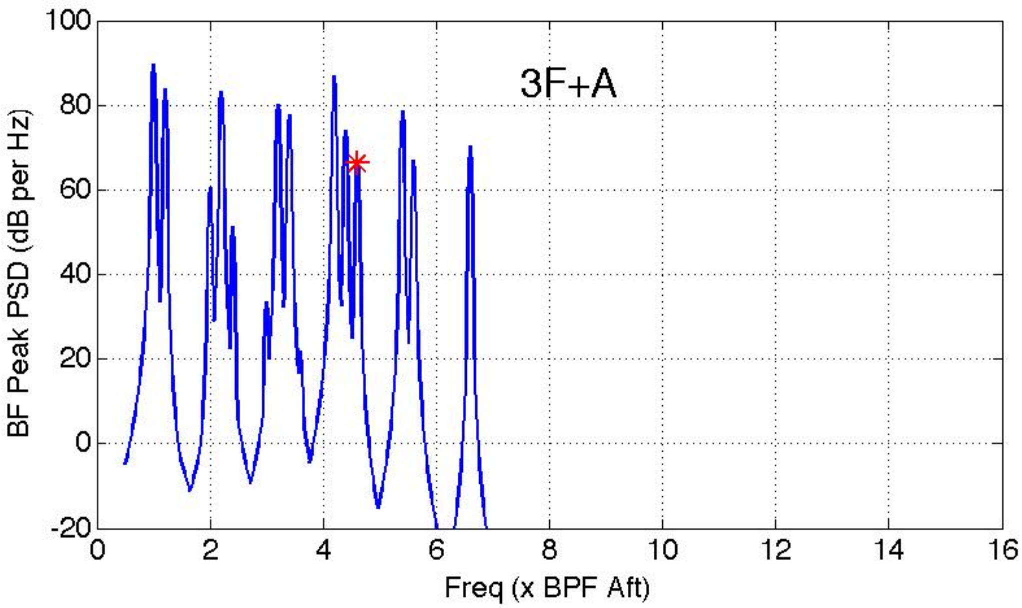

4601.9-4623.8 Hz
1.60 m
97.5 dB
98
dB
93

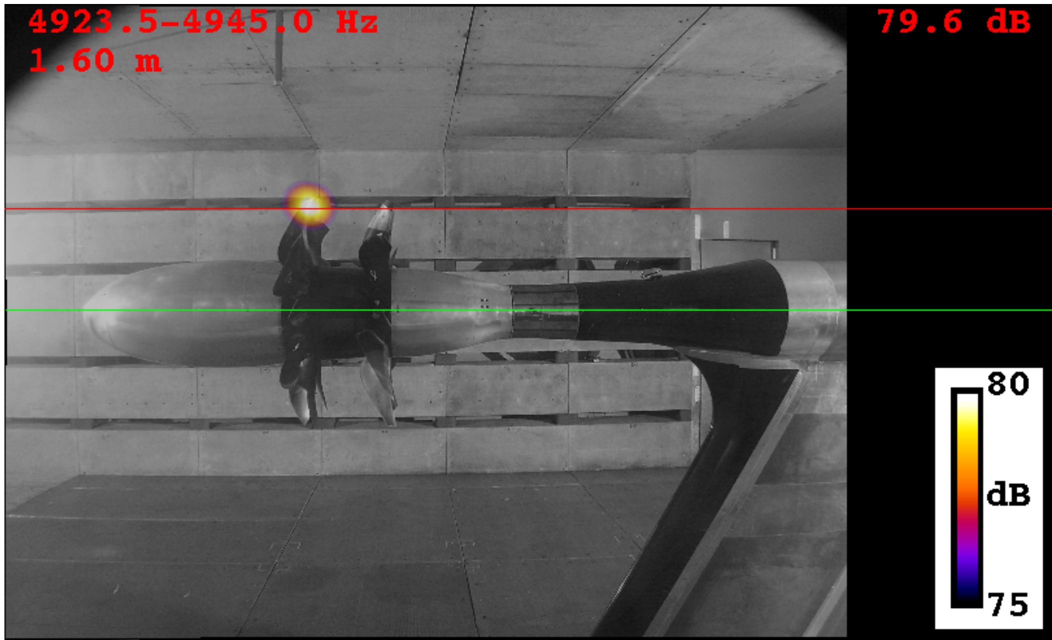

2F+2A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)

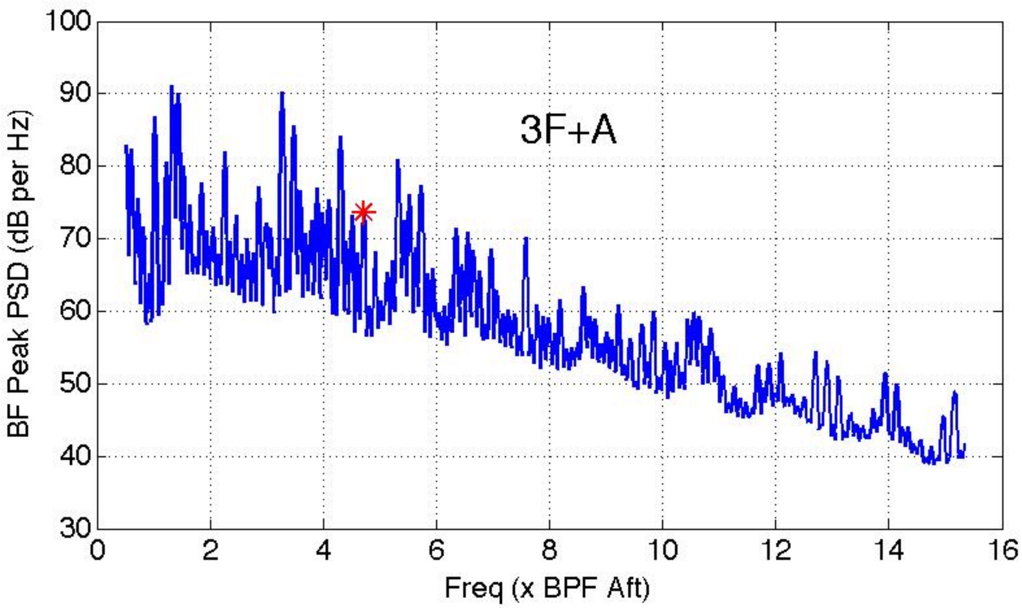

4709.0-4730.5 Hz
1.60 m
87.3 dB
87
dB
82

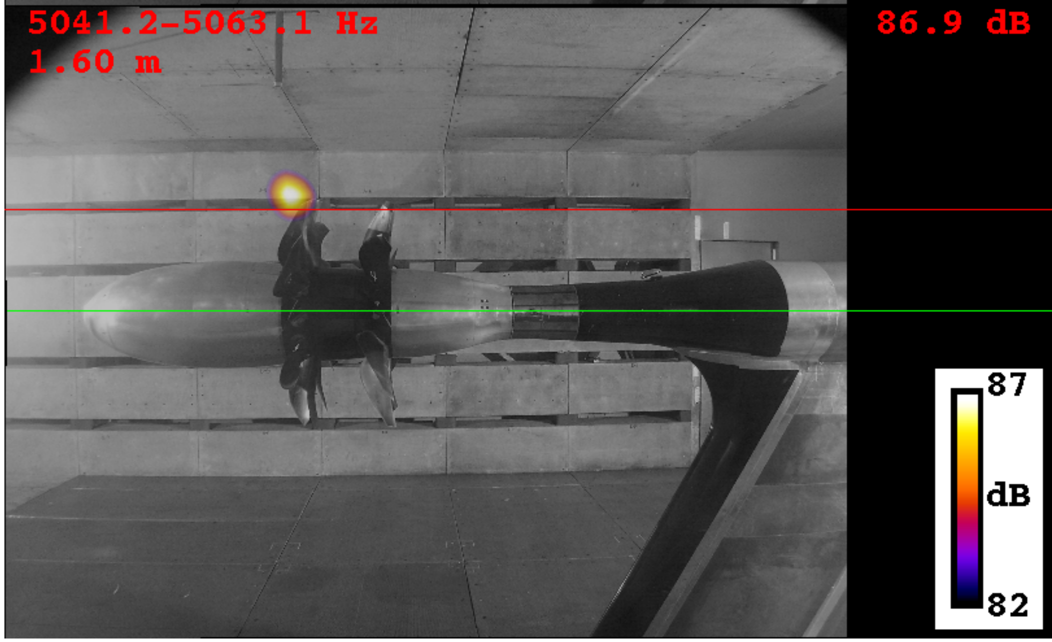

2F+2A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)

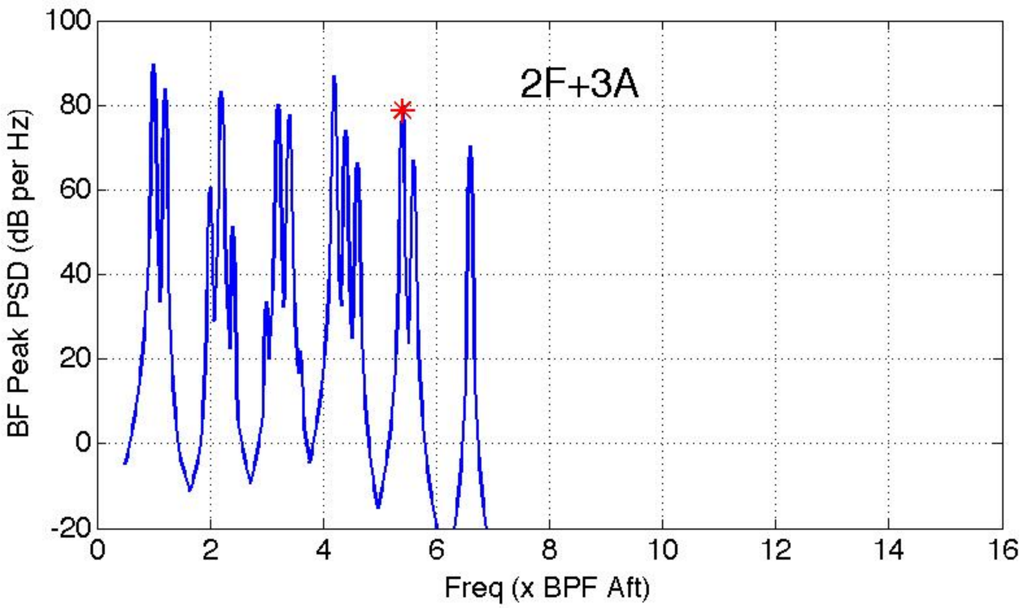

4821.5-4843.5 Hz
1.60 m
86.5 dB
87
dB
82


3F+A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)

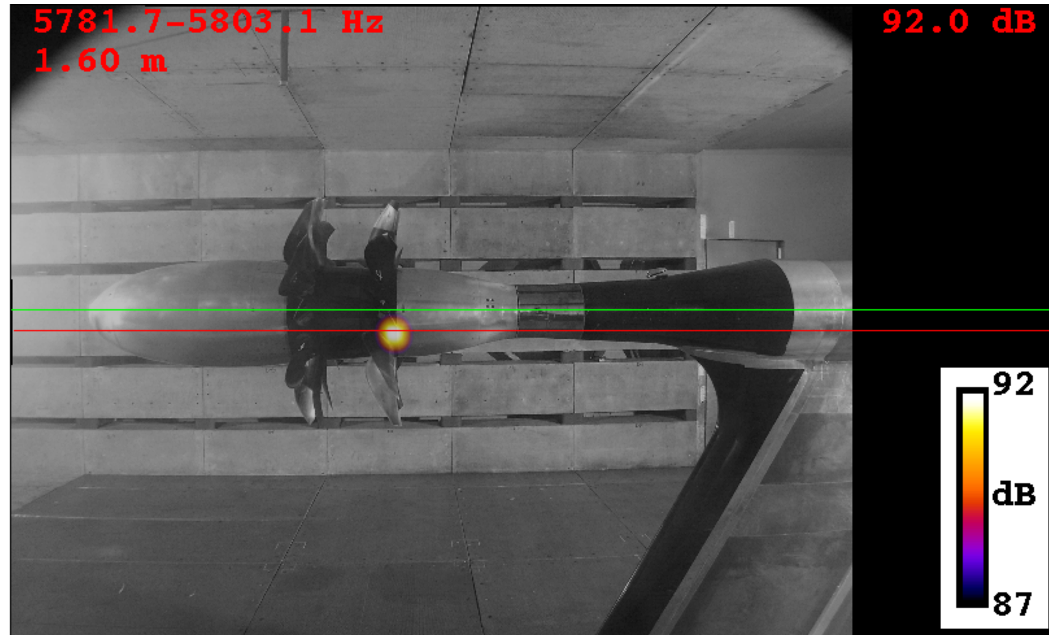

4923.5-4945.0 Hz
1.60 m
79.6 dB
80
dB
75


3F+A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)

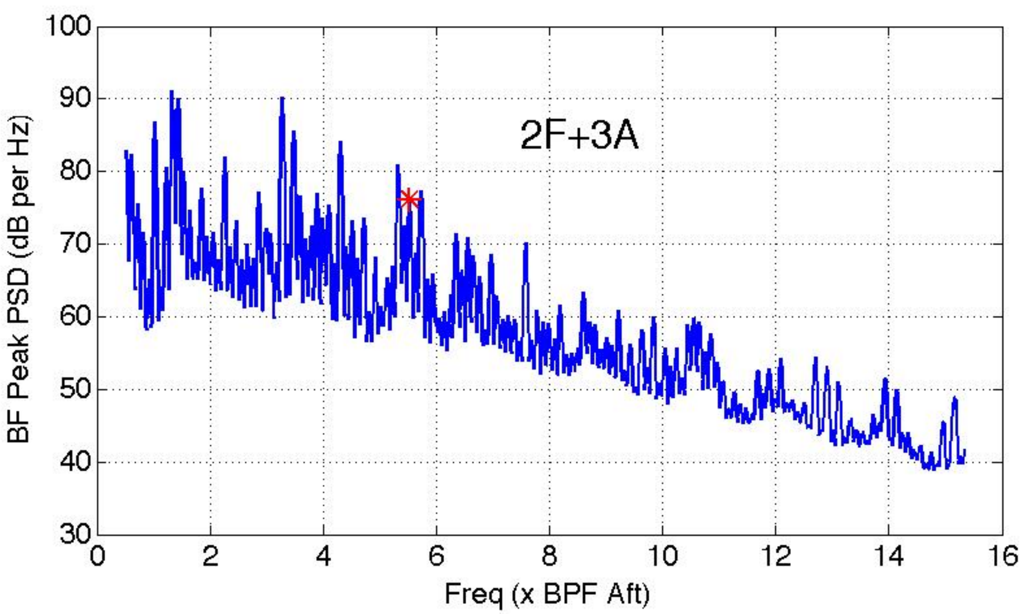

5041.2-5063.1 Hz
1.60 m
86.9 dB
87
dB
82



2F+3A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
80
60
40
20
0
-20
0
2
4
6
8
10
12
14
16

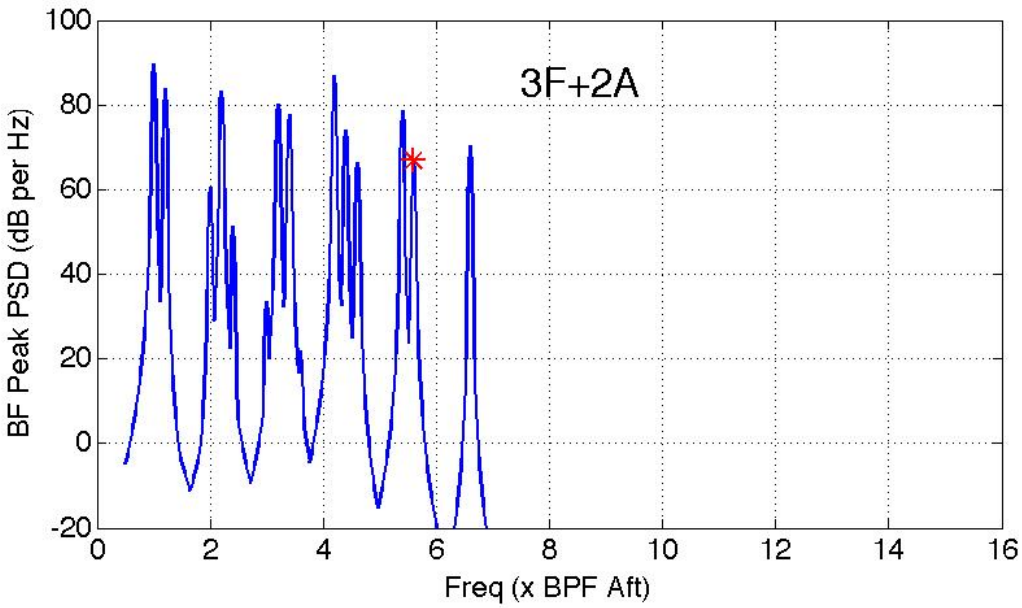


5781.7-5803.1 Hz
1.60 m
92.0 dB
92
dB
87

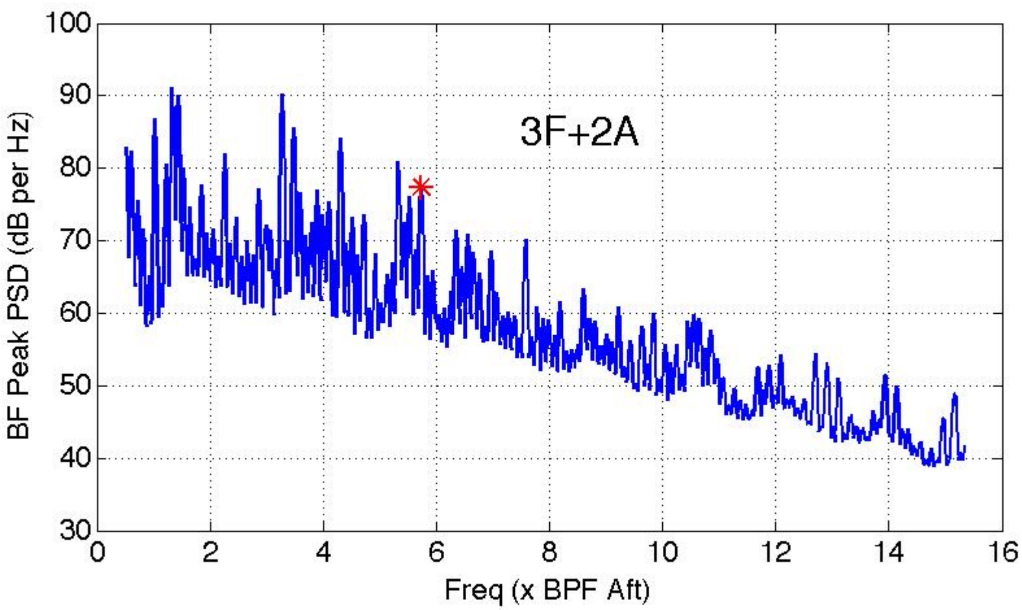


2F+3A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
90
80
70
60
50
40
30
0
2
4
6
8
10
12
14
16

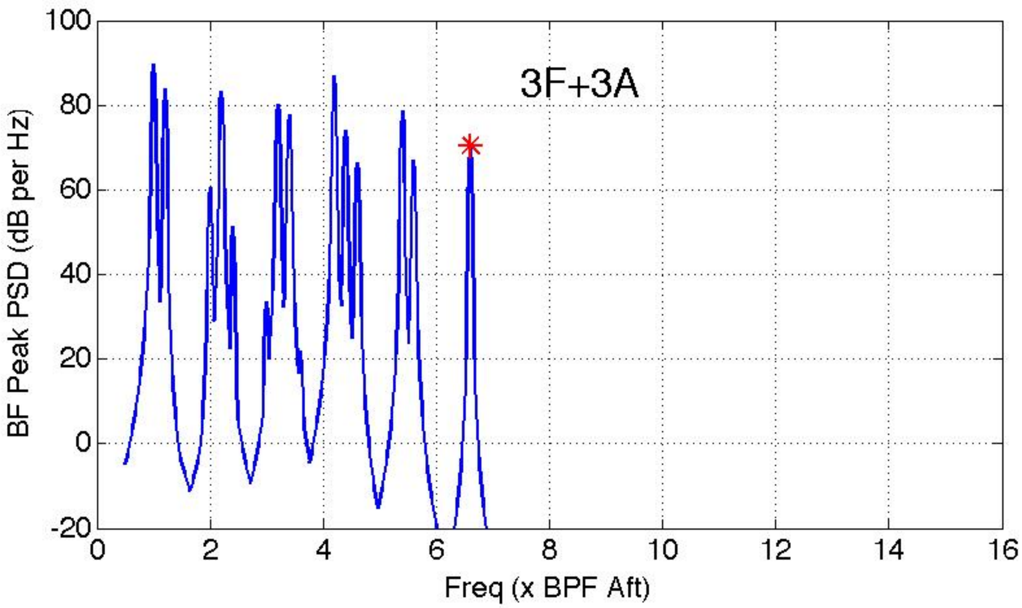
5919.8-5941.8 Hz
1.60 m
89.5 dB
89
dB
84

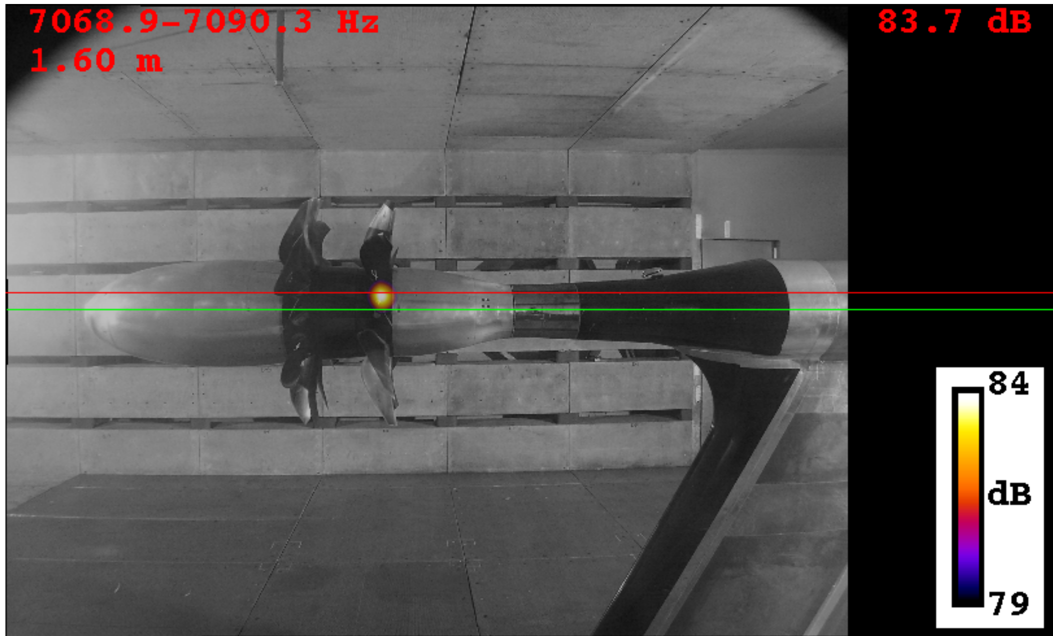

3F+2A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
80
60
40
20
0
-20
0 2 4 6 8 10 12 14 16

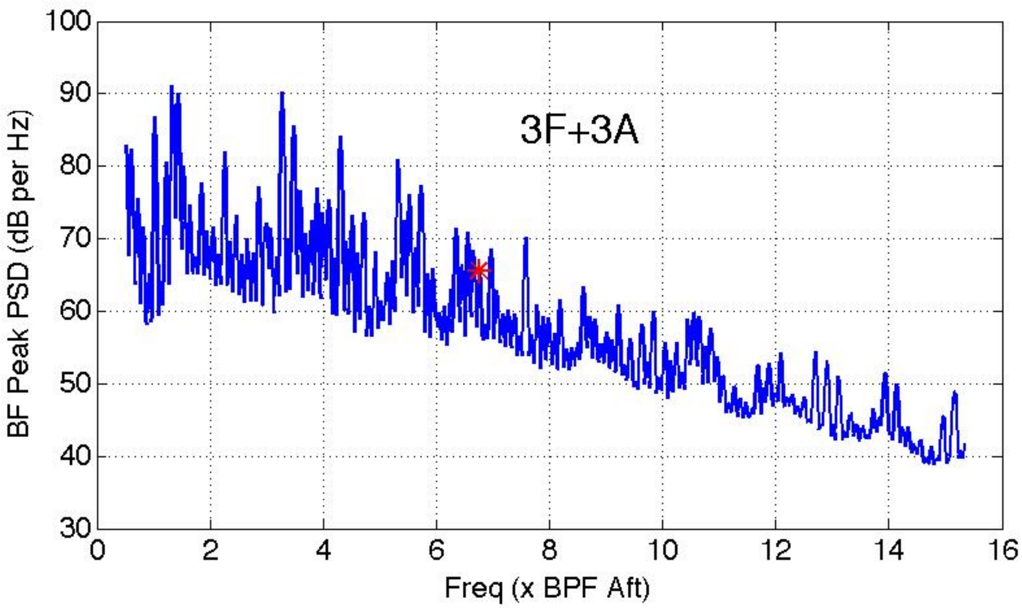

5996.2-6017.7 Hz
1.60 m
80.2 dB
80
dB
75


3F+2A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
90
80
70
60
50
40
30
0 2 4 6 8 10 12 14 16


6139.5-6161.4 Hz
1.60 m
90.7 dB
91
dB
86


3F+3A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
80
60
40
20
0
-20
0
2
4
6
8
10
12
14
16

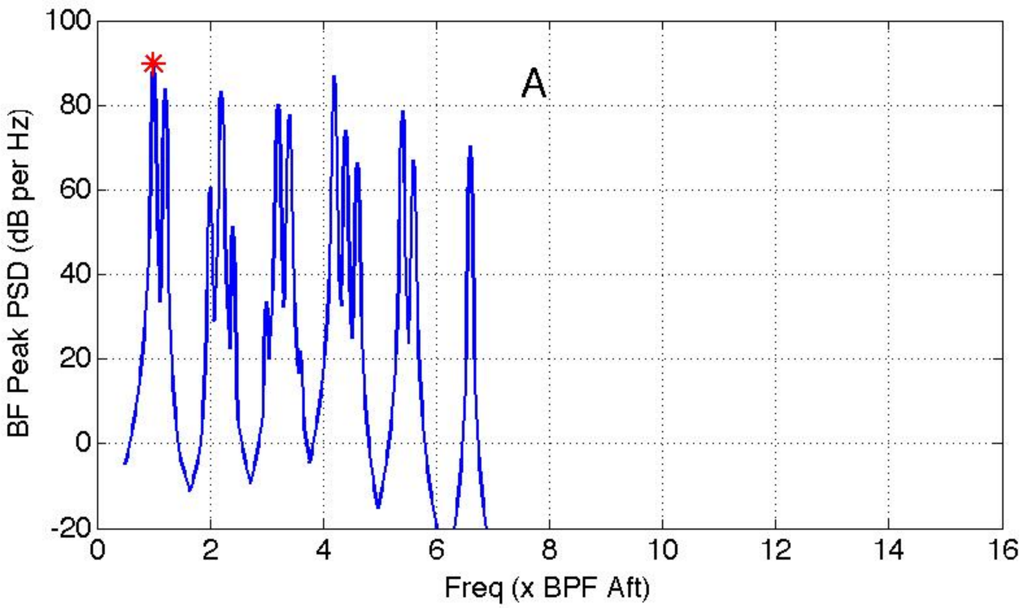

7068.9-7090.3 Hz
1.60 m
83.7 dB
84
dB
79

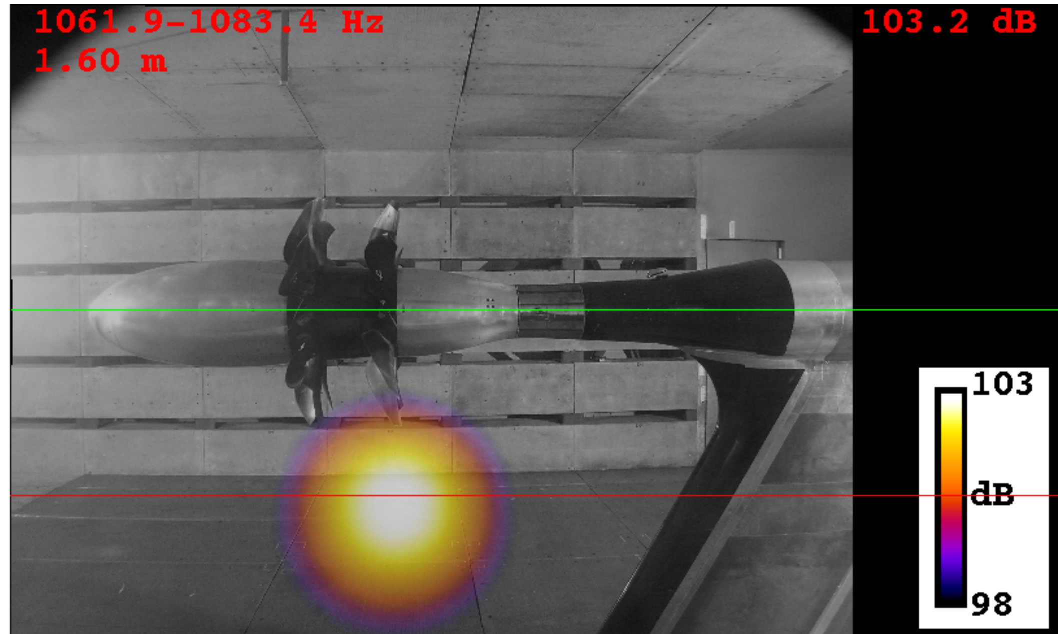

3F+3A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
90
80
70
60
50
40
30
0
2
4
6
8
10
12
14
16

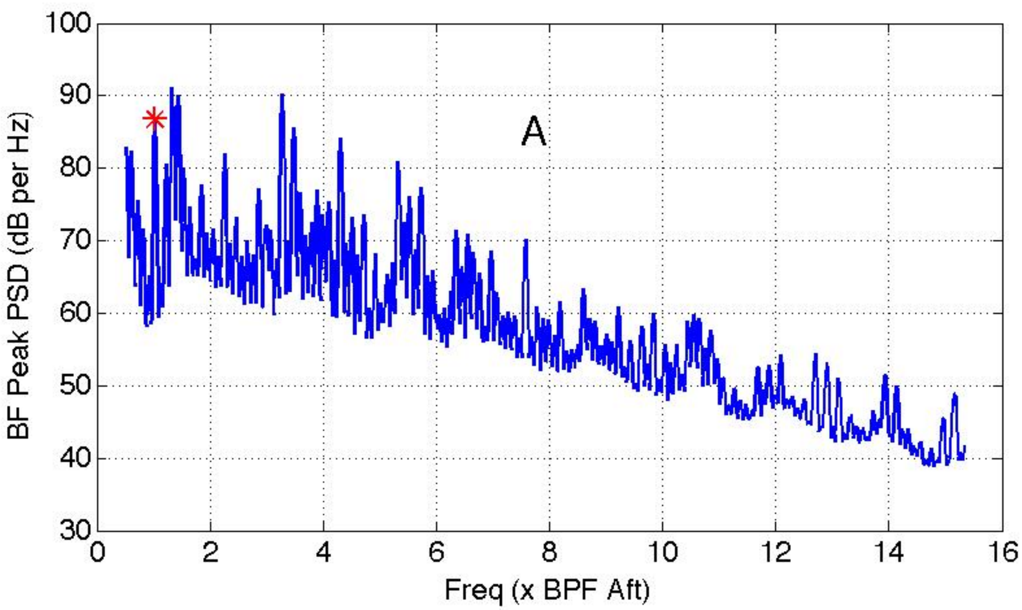

7237.8-7259.7 Hz
1.60 m
78.9 dB
79
dB
74

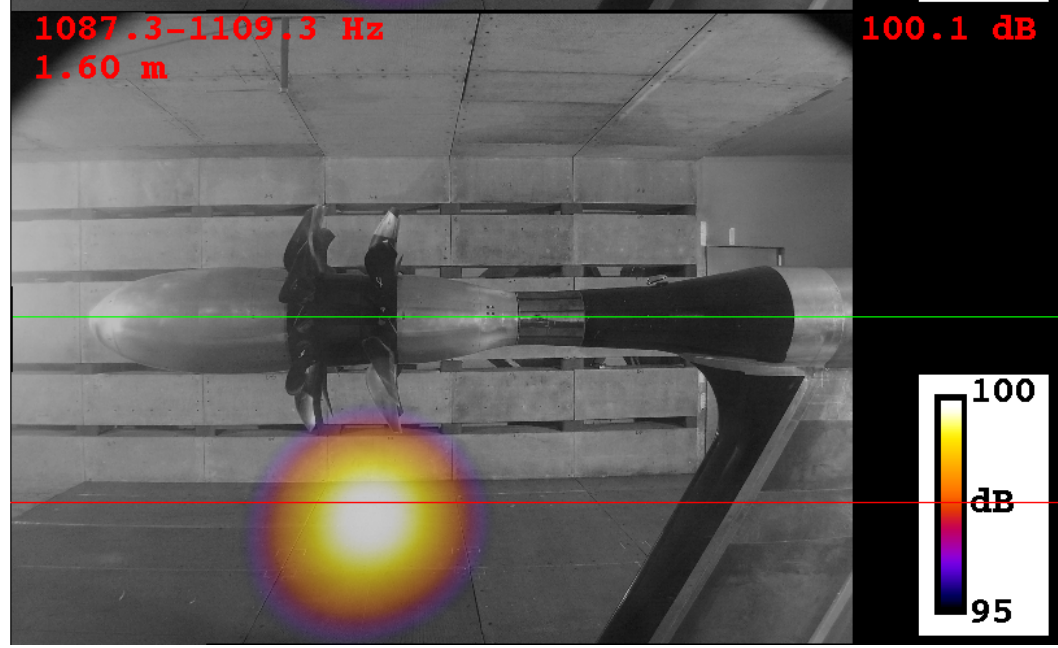
The beamform maps show that all of the tones from the simulation and many of the tones in the experimental data come from their corresponding Mach radius.

This explains the puzzling experimental results.


A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
80
60
40
20
0
-20
0
2
4
6
8
10
12
14
16


1061.9-1083.4 Hz
1.60 m
103.2 dB
103
dB
98


A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
100
90
80
70
60
50
40
30
0
2
4
6
8
10
12
14
16


1087.3-1109.3 Hz
1.60 m
100.1 dB
100
dB
95

The beamform maps show that all of the tones from the simulation and many of the tones in the experimental data come from their corresponding Mach radius.

Unfortunately, when the phased array points to the Mach radius it provides little information regarding the noise sources on the blades.

$$z^* = \frac{n_1 B_1 - n_2 B_2}{n_1 B_1 M_{t1} + n_2 B_2 M_{t2}}$$

The beamform maps show that all of the tones from the simulation and many of the tones in the experimental data come from their corresponding Mach radius.

When the phased array points to the Mach radius it provides little information regarding the noise sources on the blades.

$$z^* = \frac{n_1 B_1 - n_2 B_2}{n_1 B_1 M_{t1} + n_2 B_2 M_{t2}}$$

A different set of blades would produce the same set of Mach radii provided there were 12 front rotor blades, 10 aft rotor blades and they were rotating at the tested speed.

The beamform maps show that all of the tones from the simulation and many of the tones in the experimental data come from their corresponding Mach radius.

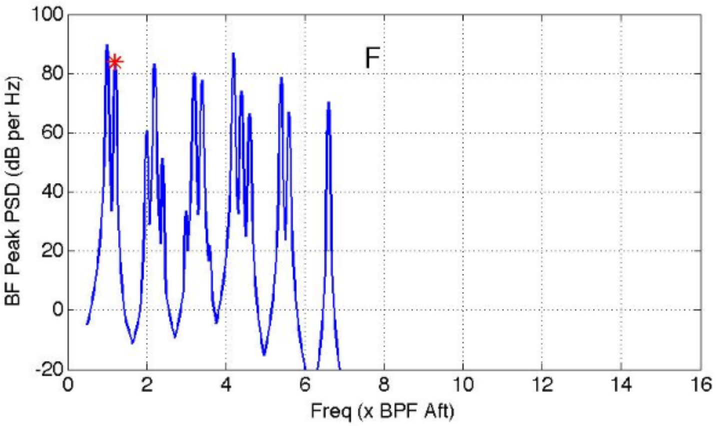
When the phased array points to the Mach radius it provides little information regarding the noise sources on the blades.

$$z^{*} = \frac{n_1 B_1 - n_2 B_2}{n_1 B_1 M_{t1} + n_2 B_2 M_{t2}}$$

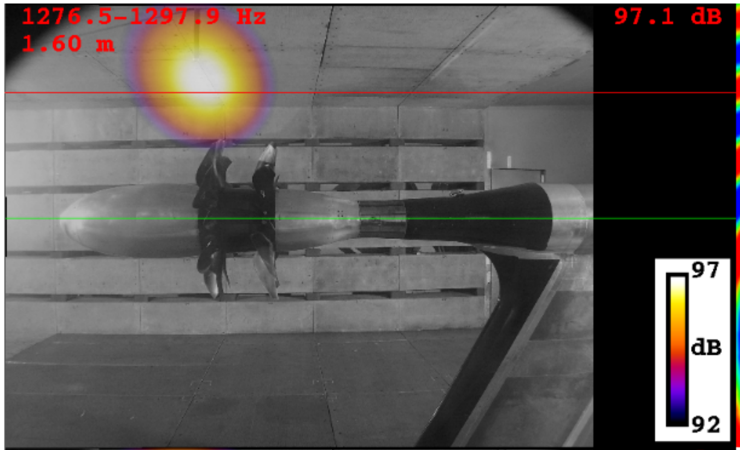
A different set of blades would produce the same set of Mach radii provided there were 12 front rotor blades, 10 aft rotor blades and they were rotating at the tested speed.

When the phased array points to the Mach radius it shows the axial location of the source in the image but does not necessarily point to the vertical location of the source.

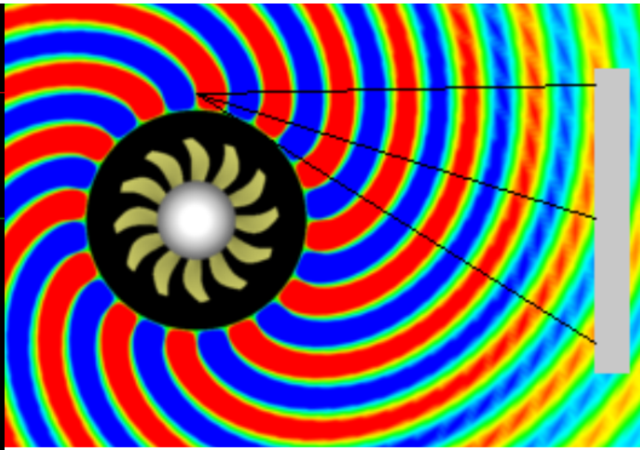
When the phased array points to the Mach radius it does not provide any more information regarding the vertical location of the source than the Mach radius equation.

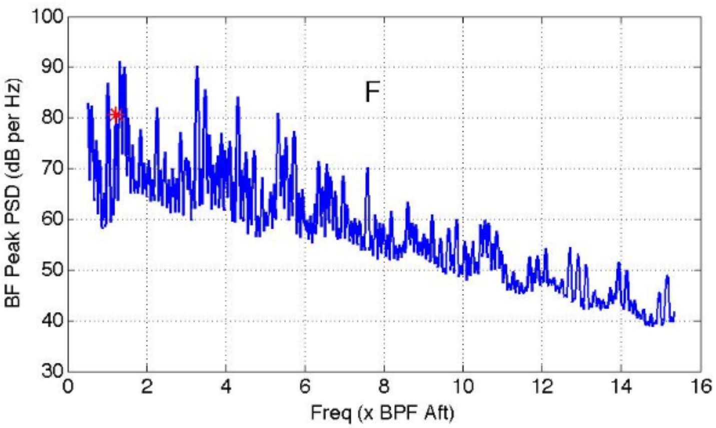


F
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)



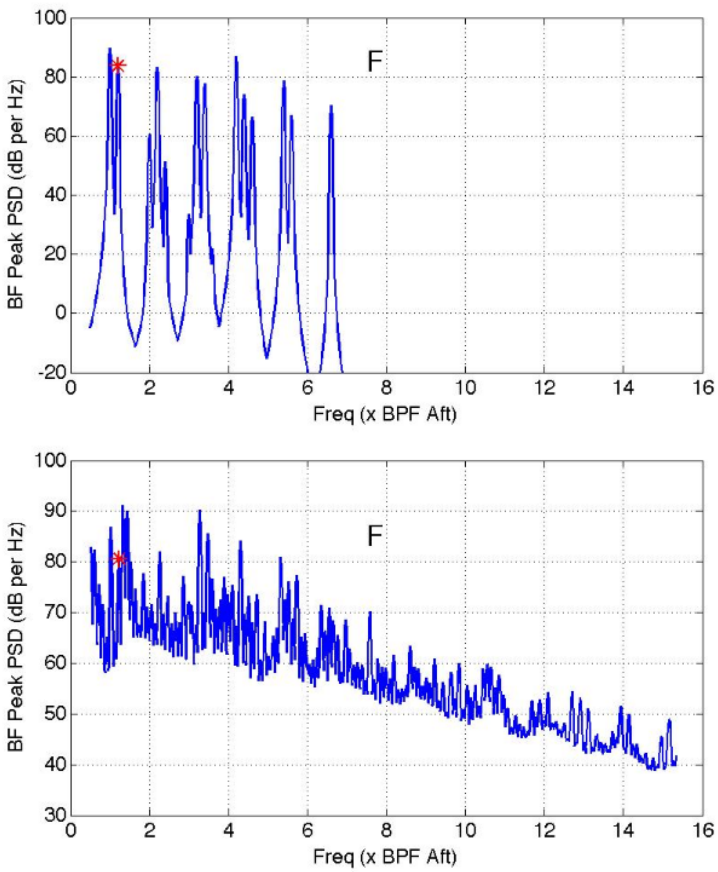
1276.5-1297.9 Hz
1.60 m
97.1 dB
97
dB
92

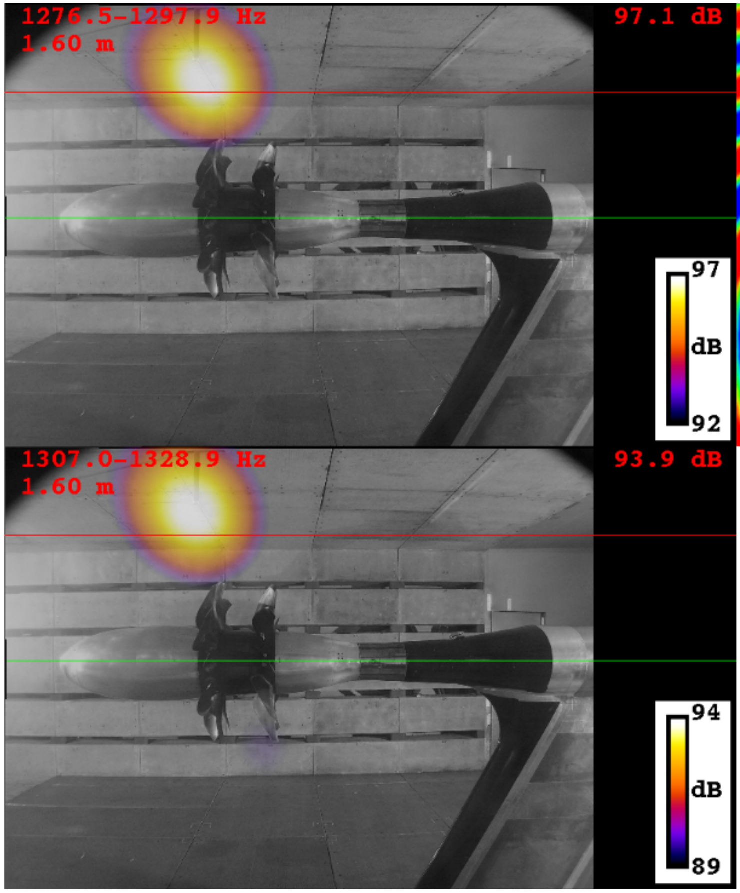


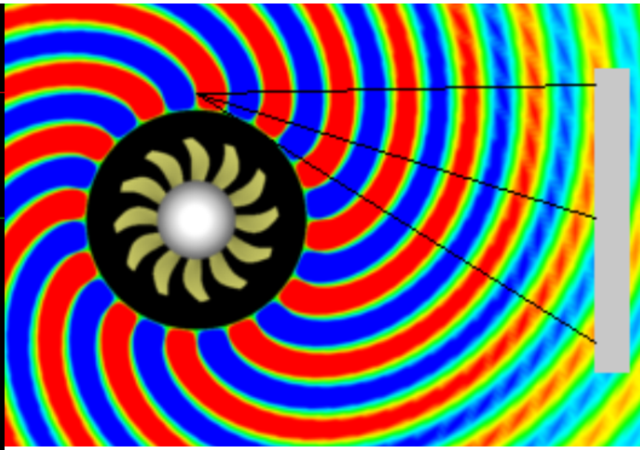


F
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)

1307.0-1328.9 Hz
1.60 m
93.9 dB
94
dB
89

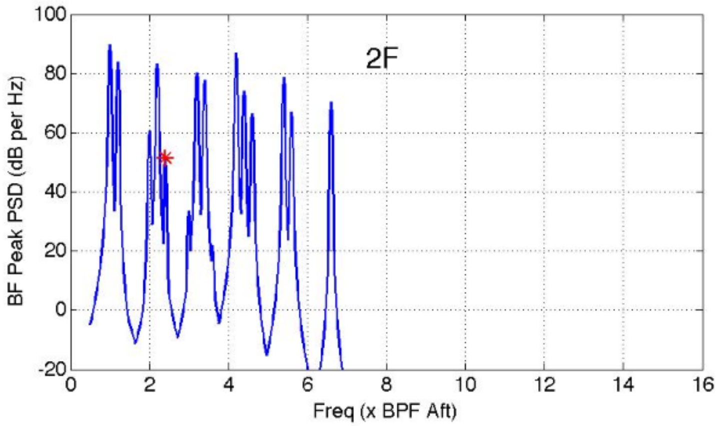




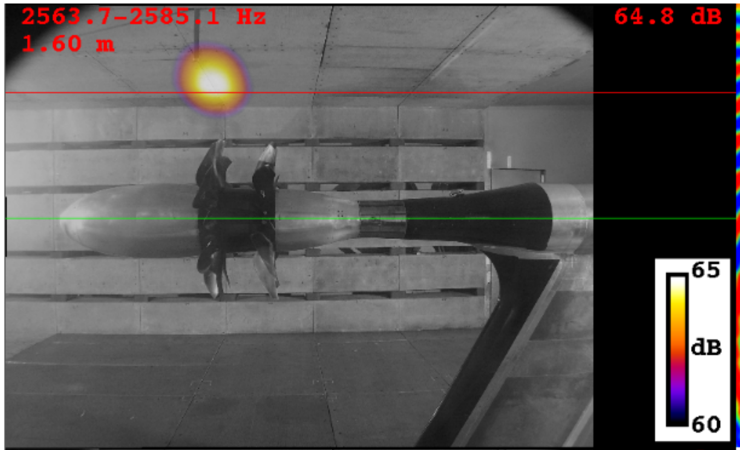


The phased array points to the Mach radius because of the spiral wave patterns created by the rotating blades.

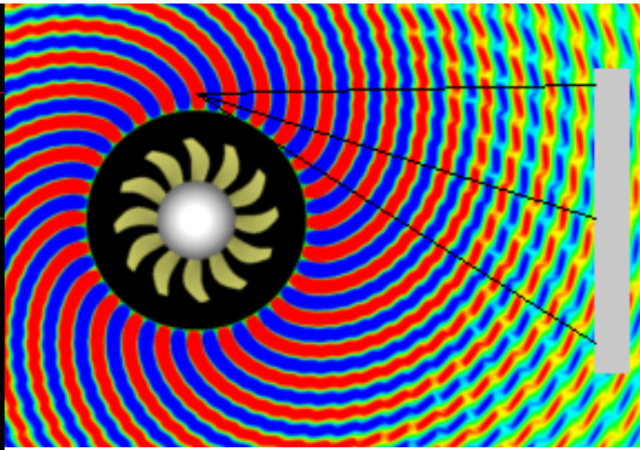
The phased array correctly points to where the noise is coming from, but the noise is not coming directly from the sources.

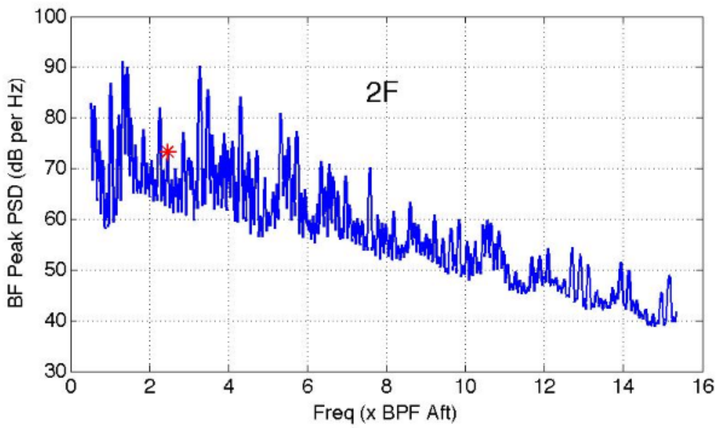


BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
2F



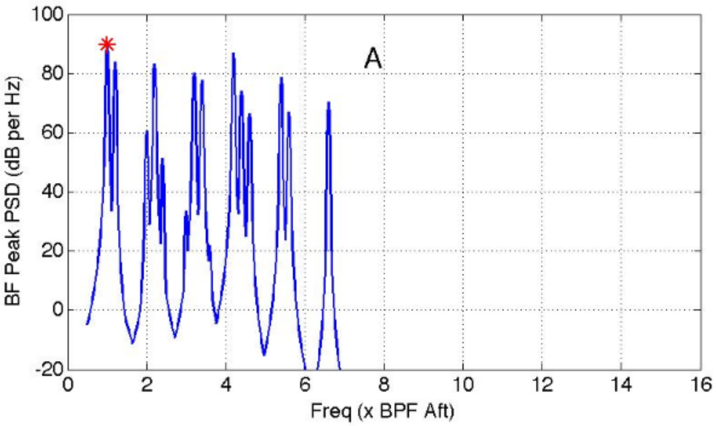
2563.7-2585.1 Hz
1.60 m
64.8 dB
65
dB
60



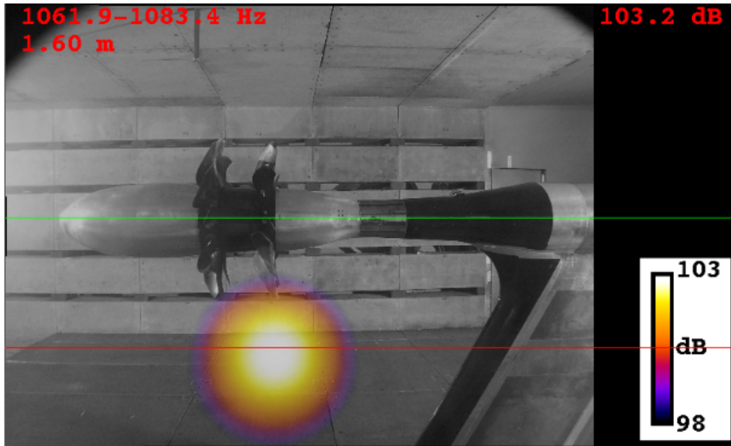


BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
2F

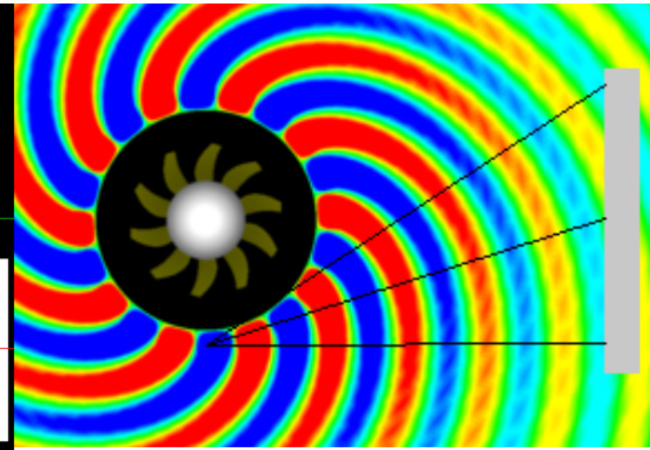
2624.9-2646.9 Hz
1.60 m
86.5 dB
87
dB
82

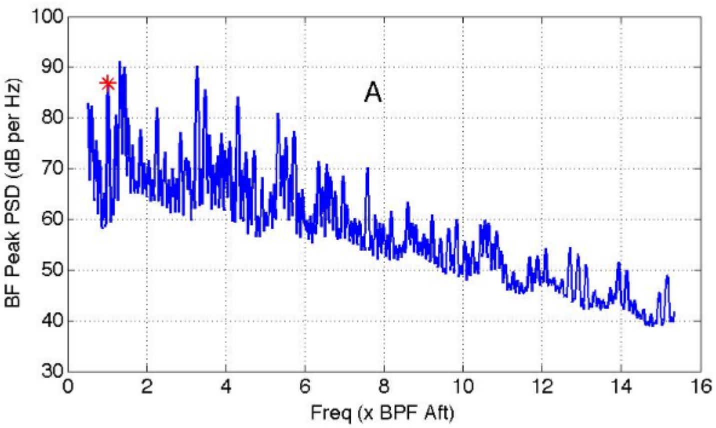


BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
A
100
80
60
40
20
0
-20
0
2
4
6
8
10
12
14
16



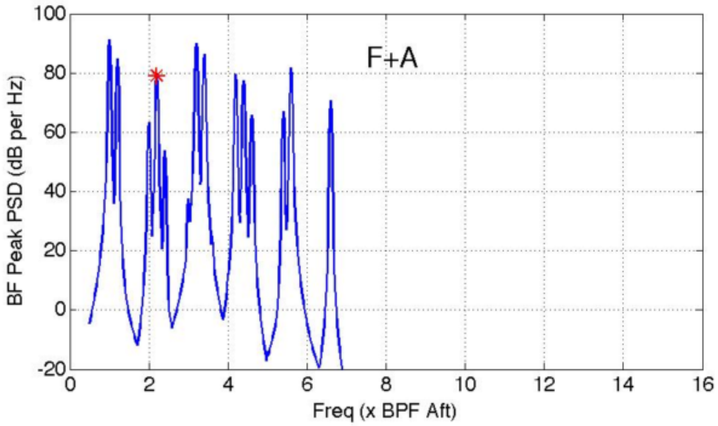
1061.9-1083.4 Hz
1.60 m
103.2 dB
103
dB
98

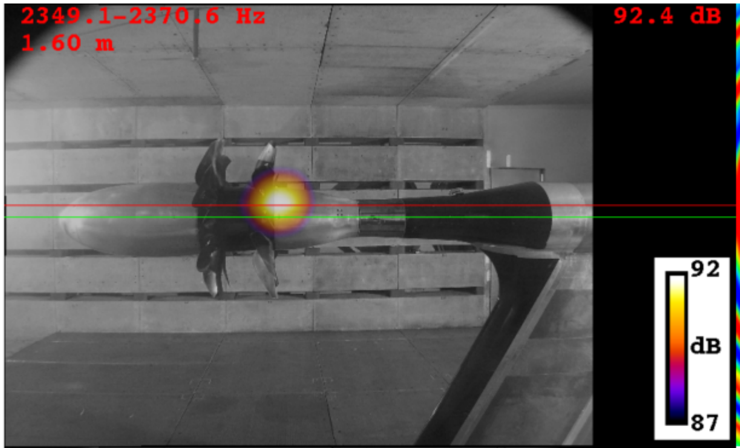


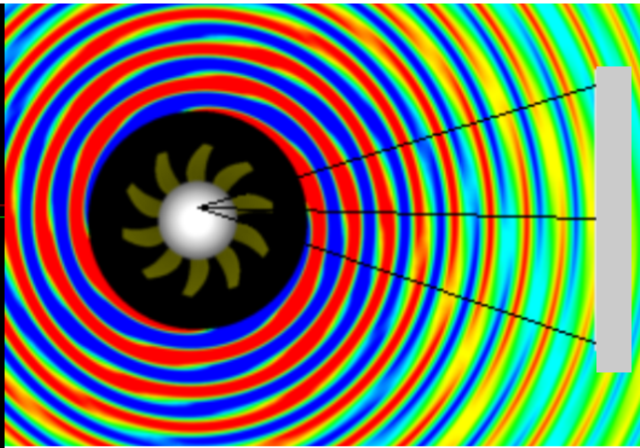


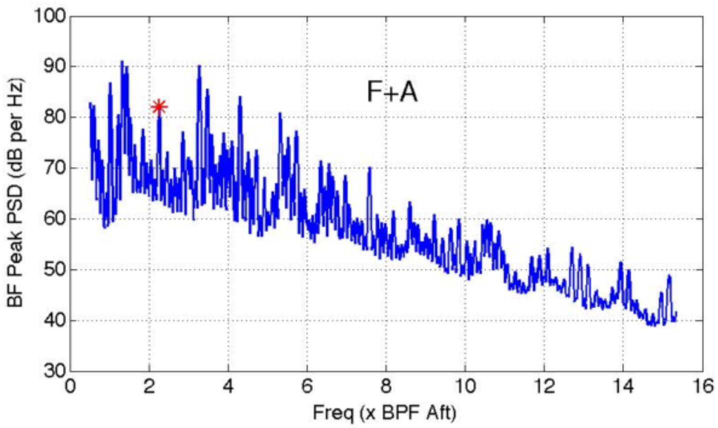
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)
A
100
90
80
70
60
50
40
30
0
2
4
6
8
10
12
14
16

1087.3-1109.3 Hz
1.60 m
100.1 dB
100
dB
95


F+A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)

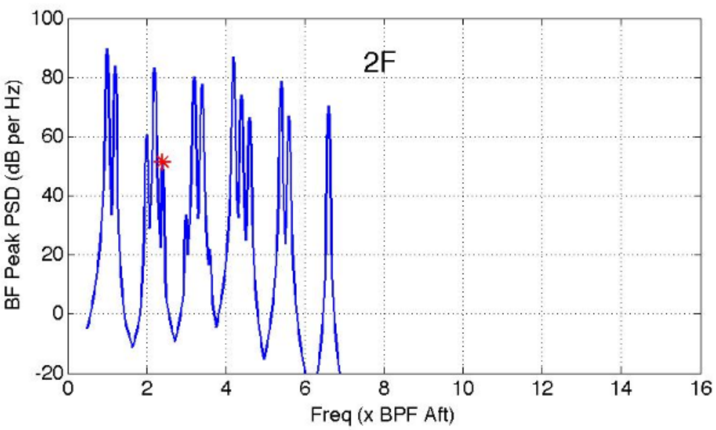

2349.1-2370.6 Hz
1.60 m
92.4 dB
92
dB
87

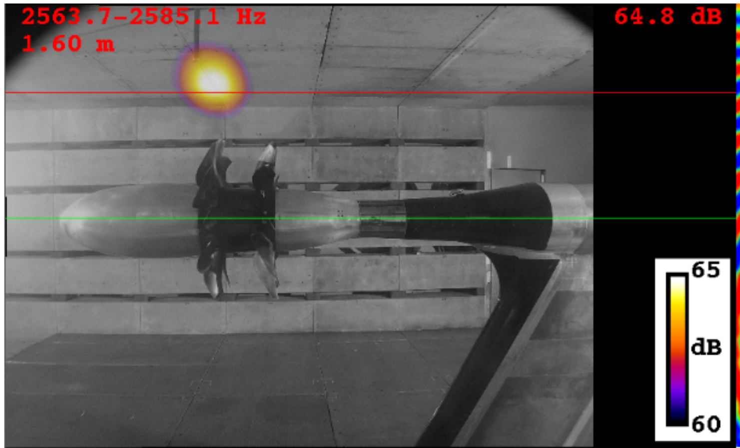


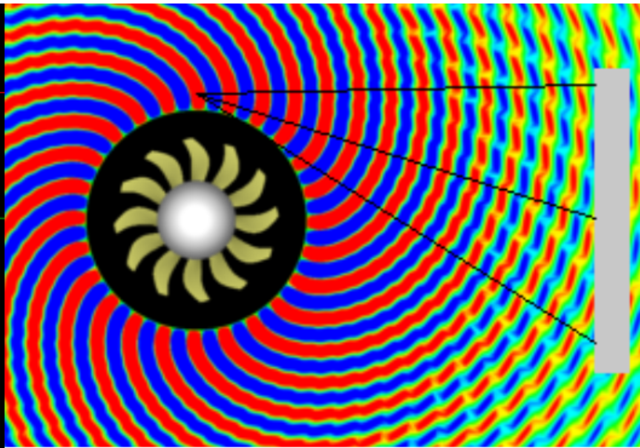

F+A
BF Peak PSD (dB per Hz)
Freq (x BPF Aft)

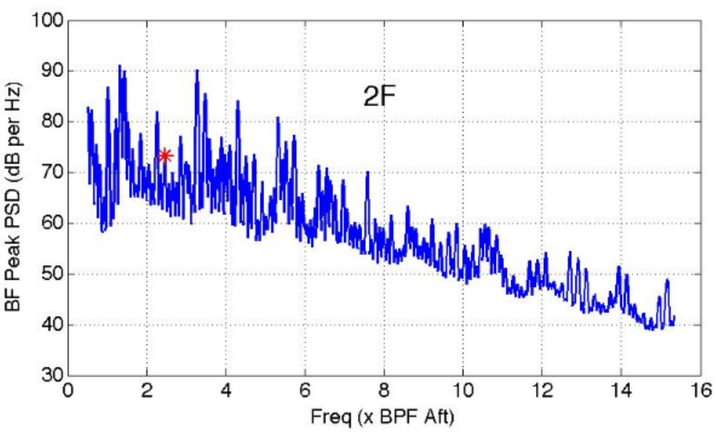

2405.3-2427.2 Hz
1.60 m
95.4 dB
95
dB
90

What about the cases in the experiment when the phased array does not point to the Mach radius?

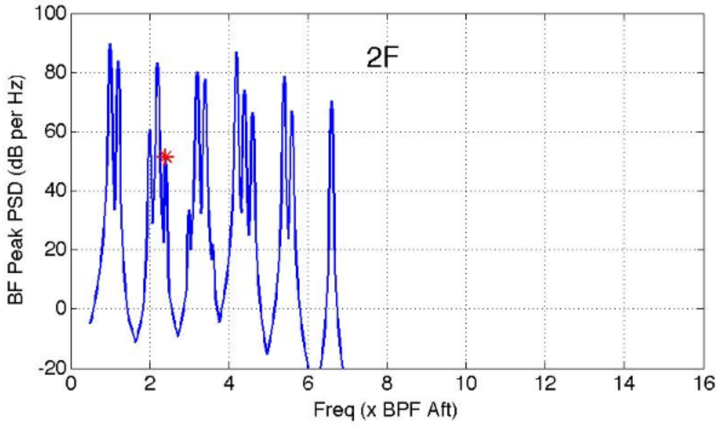


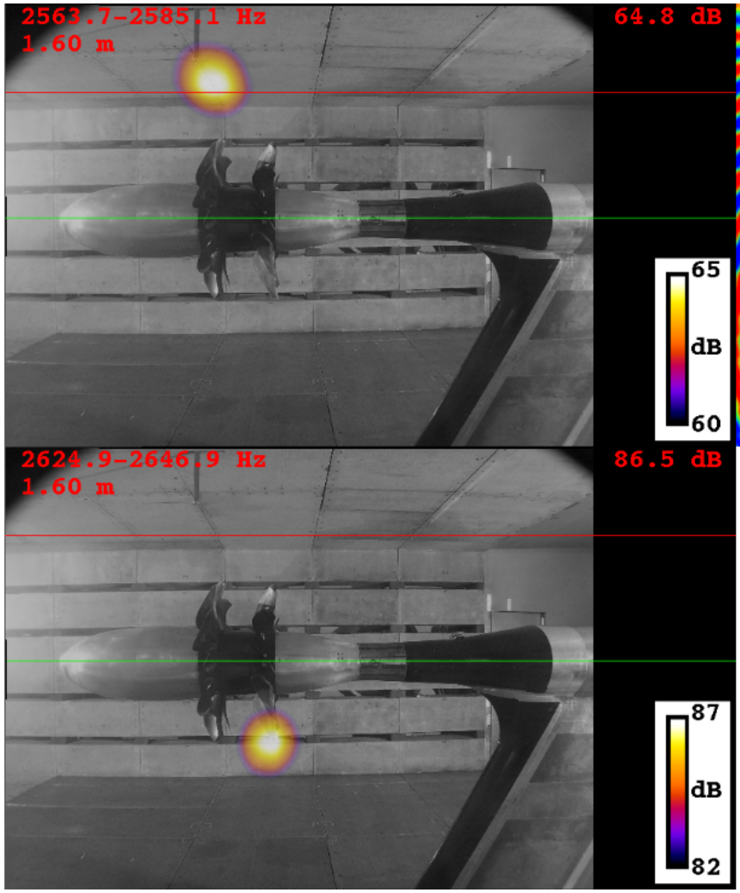


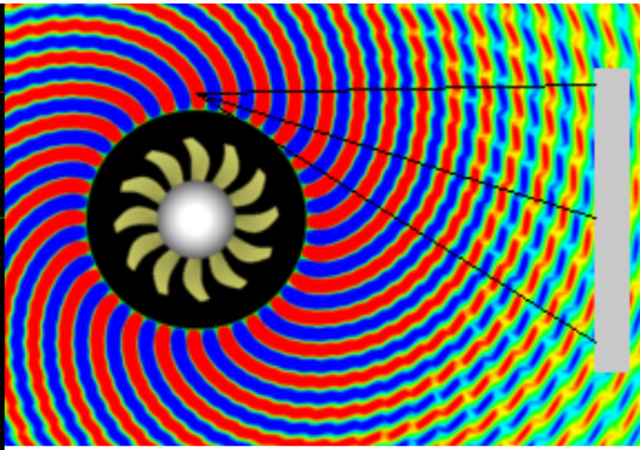


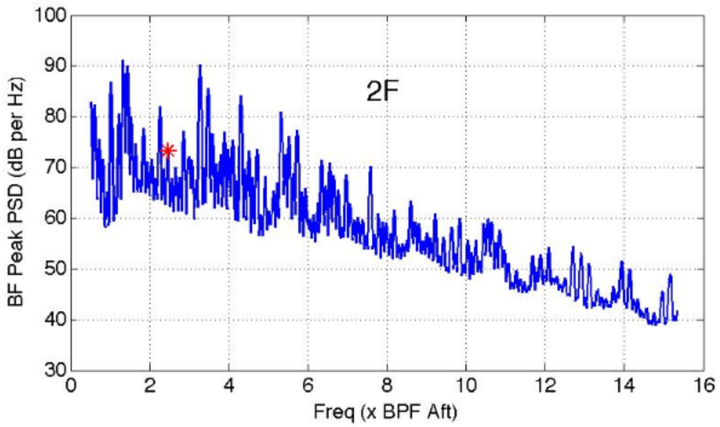


What about the cases in the experiment when the phased array does not point to the Mach radius?





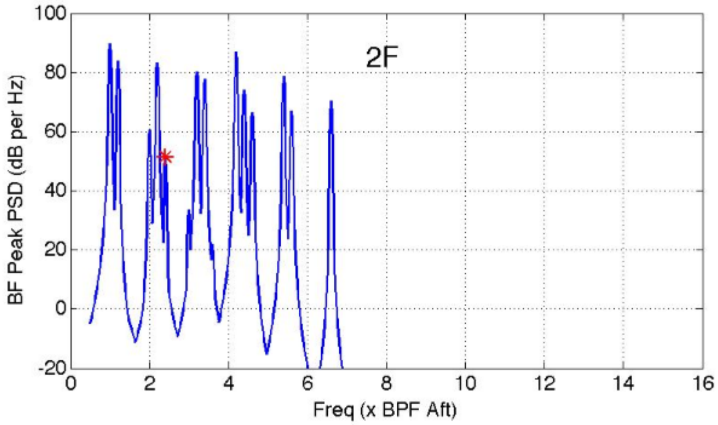


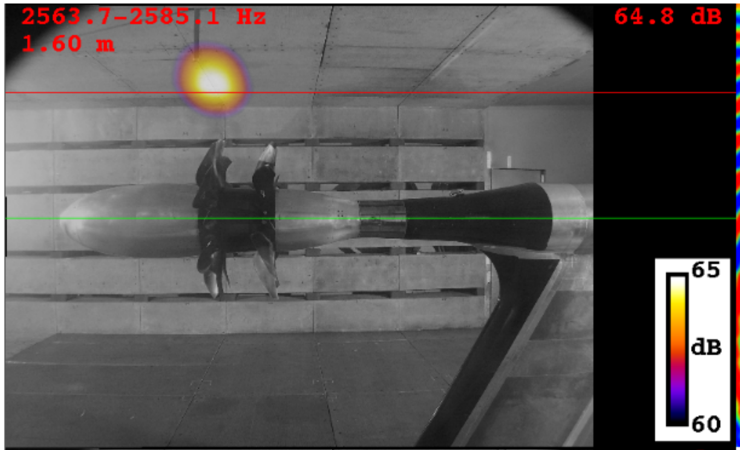


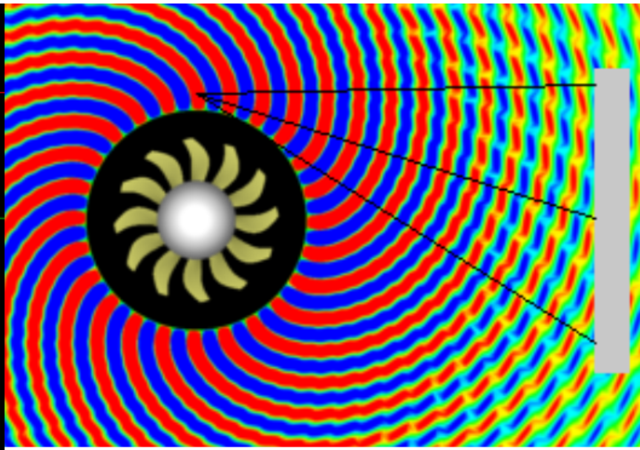
-Indicates that there may be a louder tone source in the experiment (louder than the thickness and loading noise included in the simulation)

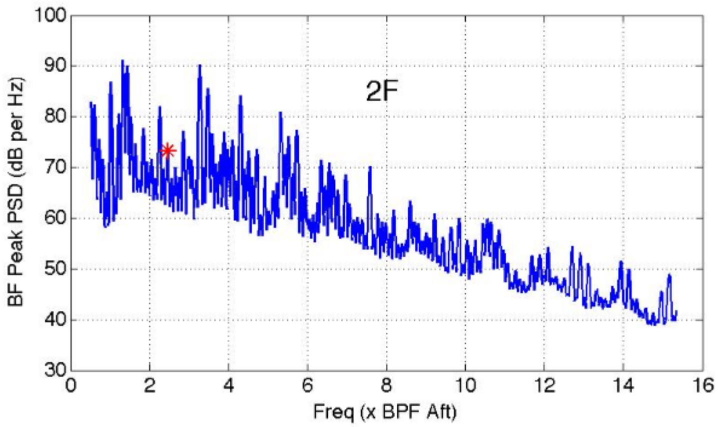
What about the cases in the experiment when the phased array does not point to the Mach radius?

Does the phase array point to the actual source?



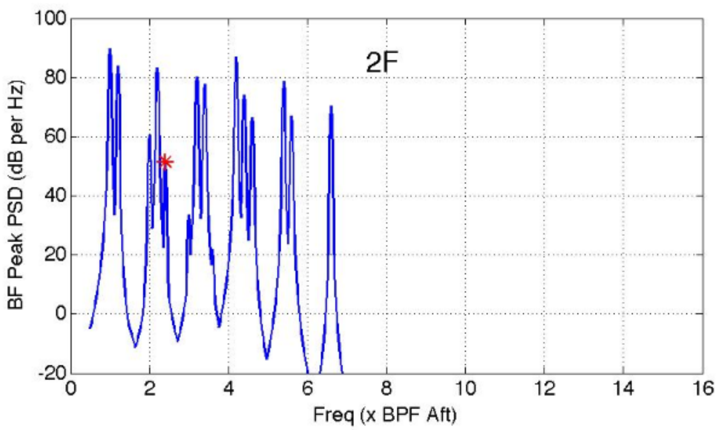


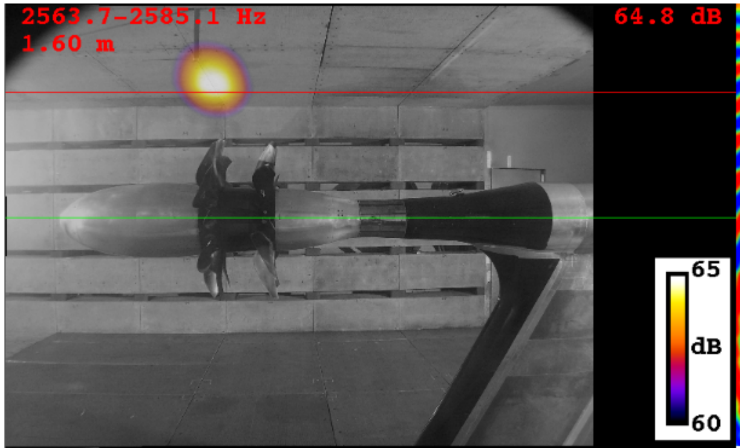


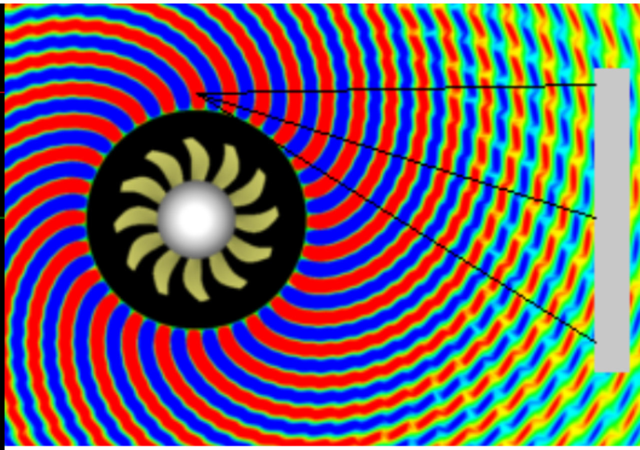


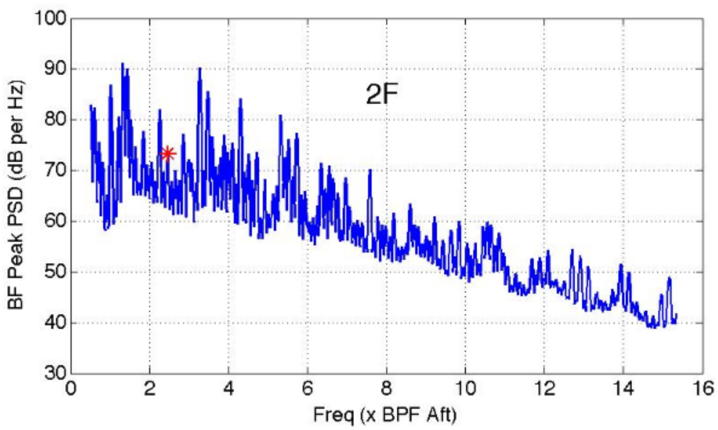
What about the cases in the experiment when the phased array does not point to the Mach radius?

Does the phase array point to the actual source?



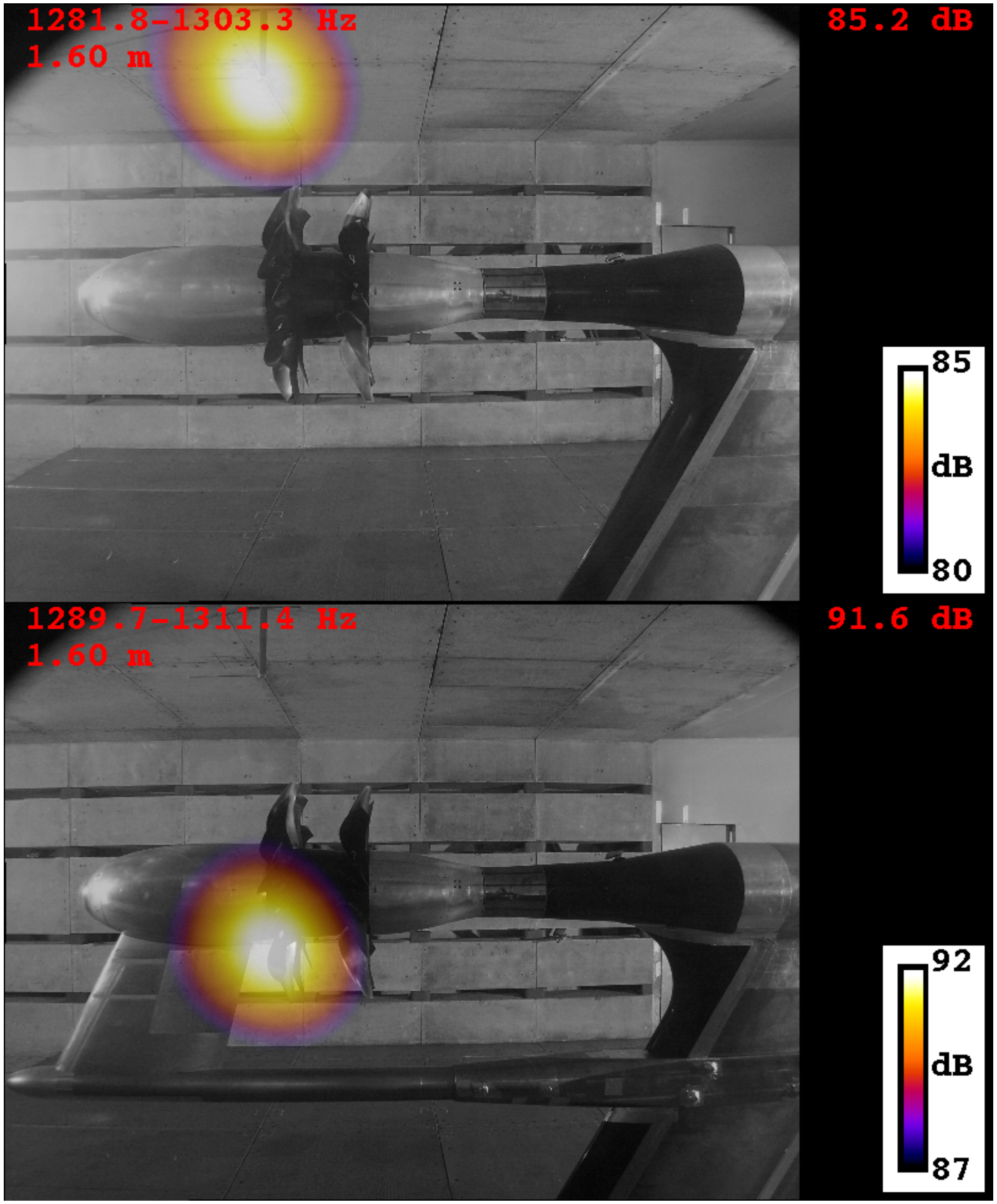






-probably not if the source is rotating since a rotating tone source will create spiral wave patterns.

No pylon (rotating tone source)



Pylon (nonrotating tone source)

1F tone

Approach Blade Angle Setting

M=0.2

0° AOA

RPMC=6325

Summary

Beamform maps have been generated from 1) simulated data generated by the LINPROP code and 2) actual experimental phased array data obtained on the GE Counter-rotating open rotor model.

The beamform maps show that many of the tones in the experimental data come from their corresponding Mach radius.

If the phased array points to the Mach radius associated with a tone then it is likely that the tone is a result of the loading and thickness noise on the blades. In this case, the phased array correctly points to where the noise is coming from and indicates the axial location of the loudest source in the image but not necessarily the correct vertical location.

If the phased array does not point to the Mach radius associated with a tone then some mechanism other than loading and thickness noise may control the amplitude of the tone. In this case, the phased array *may or may not* point to the actual source. If the source is not rotating it is likely that the phased array points to the source. If the source is rotating it is likely that the phased array indicates the axial location of the loudest source but not necessarily the correct vertical location.

Summary

These results indicate that you have to be careful in how you interpret phased array data obtained on an open rotor since they may show the tones coming from a location other than the source location.

With a subsonic tip speed open rotor the tones can come form locations outboard of the blade tips. This has implications regarding noise shielding.

NASA